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THE FREE-SWIMMING PLANKTONIC COPEPODA
GEOGRAPHICAL DISTRIBUTION

BY

R. B. SEYMOUR SEWELL, C.I.E., Sc.D., F.R.S.
(Lieut.-Colonel, I.M.S. [ret.])

WITH TWENTY-FOUR TEXT-FIGURES AND TWO CHARTS

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See page 364 - for discussion of gyrals

WITH TWENTY-FOUR TEXT-FIGURES AND TWO CHARTS.

HISTORICAL.

One of the earliest attempts to provide an adequate explanation of the distribution of the Copepoda and other Crustacea is that of Dana (1853), who, however, dealt with the Crustacea as a whole and thus included many forms that are not planktonic except in their larval stages. He constructed a chart in which the surface of the oceans is divided into zones by what he terms "isocrymal" lines: these are lines of equal surface temperature during the coldest thirty consecutive days of the year, as opposed to "isothermal" lines that are based on summer or winter temperature or on the average temperature in any given month of the year. Semper (1883) recognized that oceanic currents may serve as means for the distribution of species, but may also act as limiting factors hindering their extension; but he also further recognized that these results may be modified or even be completely abolished by other factors, so that planktonic organisms may be carried by currents into unfavourable regions, where they are destroyed, and he points out that "many animals are susceptible to variations of temperature, consequently, if any warm-water animals are borne by a current from the region of warm seas into a cold one, they must in all probability perish very soon." Chun (1886) agrees with Semper, and considers that currents and winds of constant duration may assist in the horizontal distribution of pelagic organisms, but he also considers that they may in many instances act as impassable barriers.

Since that date many authors have attempted to correlate the distribution of most of the various forms of planktonic organisms with the surface currents, and an especially noteworthy attempt was that of Pelseneer (1887), in which he divided the oceanic surface into as many as ten Provinces, each connected with a definite current system; and he gave it as his opinion that "each great surface area of water coinciding with an important current or system of currents forms a distinct pelagic province." Giesbrecht (1892), however, only recognized three zones of distribution among the Copepoda, namely an Arctic zone, extending southwards to about Lat. 47° N., which is poor in the number of species; a warm tropical and subtropical zone, which is rich in species; and an Antarctic Zone that extended northwards to about lat. 44° S., that also is poor in species. He did, however, recognize that the northern region must be subdivided into Atlantic and Pacific sub-regions. Although he was convinced that the main factors in delimiting these three regions were temperature and light, he refused to admit that the ocean currents could be considered as forming faunistic regions, so far as the Copepoda were concerned, and he based this view on the fact, firstly, that as many as 32 per cent. of the warm-water species, known at that time, were common to both the Atlantic and Pacific Oceans, in spite of the fact that they are separated by the American continent, and second, that the " Gulf Stream," of which the eastern part is one of the best known regions, was intersected by the " barrier " between his warm and cold north faunistic regions. Although Fewkes (1888) had put forward the suggestion that " the differences in temperature of the surface of the ocean is one of the most important factors in determining the character of pelagic organisms. . . . When the temperature of the deep sea becomes a surface temperature, we may look for allies of deep-sea animals," Giesbrecht concludes that his three faunistic regions hold good not only for surface-living species but also for those living in the deep strata, and he remarks that " one does not meet with the deep-sea species of warm seas even among the arctic species " ; he does, however, admit that the oceanic currents may bring about local and temporary inequalities in the distribution of the species.

The following year Haeckel (1893), in his " Plankton Studies," put forward the view that " by far the most important of all the causes which determine the changing and irregular distribution of the Plankton in the seas are the marine currents," and that " the unequal distribution of plankton in the ocean is in great part the direct result of the ocean currents." Haeckel further recognized that the influence of the currents must be extended to the movements of the deeper layers, which he termed the Bathycurrents, and he remarks, " the Bathycurrents are of great importance for the irregular constitution and distribution of the plankton." Dahl (1894) extended Giesbrecht's scheme of subdivision of the ocean and recognized in the North Atlantic Ocean as many as four separate zones, namely, an Arctic Zone, a Temperate zone, a Sub-tropical zone and a Tropical zone. Dahl clearly points out that the boundaries of his regions do not correspond to geographical latitudes but are determined by the surface currents : thus, as regards his Arctic region, he notes that the characteristic forms are carried to the south in the Labrador Current, while his Tropical region is extended to the north in the Florida Stream.

The schematic subdivision of the surface waters of the oceans has been carried a stage further by Steuer (1933). In this paper he has given a map indicating the subdivisions of the oceans into no less than seven zones in the Atlantic and Pacific areas and five in the Indian Ocean, and we thus have the following zoo-geographical areas :

I. A circum-polar Arctic region.

II. A sub-arctic zone, subdivided into
    (A) an Atlantic sub-region, and
    (B) a Pacific sub-region.

III. A sub-tropical zone, subdivided into
    (A) a North Atlantic sub-region, and
    (B) a Pacific sub-region.

IV. A Tropical zone, subdivided into
    (A) an Indo-Pacific sub-region, and
    (B) an Atlantic sub-region.

V. A southern Sub-tropical zone, subdivided into
    (A) a southern Atlantic sub-region,
    (B) an Indian sub-region, and
    (C) a south Pacific sub-region.

VI. A Sub-antarctic circum-polar zone, and finally

VII. An Antarctic circum-polar zone.

Of these various regions he regards the circum-polar sub-arctic and sub-antarctic regions as transition zones.

A comparison of this chart (Steuer, 1933, p. 292, fig. 8) with a chart of the surface currents of the great oceans reveals such a close similarity that by applying the one to the other we can at once recognize that each region is in reality a part of a particular current system : the circum-polar Arctic region is the region of the Arctic Ocean with its southward extension down the north-east coast of America in the Labrador current, and there should be a similar extension, not indicated by Steuer, of this region southwards along the north-east coast of Asia past the Kamchatka Peninsula to Japan, corresponding to the Okhotsk or Oya-Shio Currents. Fuchs (1881) pointed out that although the Japan Sea is characterized by a Tropical fauna that can be traced unusually far to the north, namely lat. 42° N., whereas the Okhotsk Sea is typically arctic, certain arctic species penetrate into the Japan Sea, being carried there by the Kurile Current through the Sangar Strait.

The sub-artic Atlantic and Pacific sub-regions correspond with the currents of the Gulf Stream and the North Atlantic Drift in the North Atlantic and the Kuro-Shio and Californian currents in the North Pacific Ocean respectively. The Sub-tropical zone, as Steuer points out, corresponds in the Atlantic with the region of the Sargasso Sea and the Canaries current, and in the Pacific Ocean with the corresponding area enclosed by the clock-wise circulation of the surface currents in that region. The Tropical zone corresponds to the great North and South Equatorial currents, together with the Contra-equatorial current in all three Oceans, the Indian and Pacific regions being interconnected by numerous channels through the Malay Archipelago ; and this zone is extended southwards in the Atlantic Ocean by the Brazil current and in the Indian Ocean by the Agulhas current. The southern Sub-tropical zone corresponds in each of the three oceans with the central and southern regions of the great counter-clockwise movement of the surface water in the southern part of each ocean. The circum-polar sub-antarctic zone corresponds to the West Wind Drift. And, finally, the circum-polar Antarctic zone corresponds to the true Antarctic region. In an earlier work Steuer (1910) remarks that the different zoo-geographical regions of the plankton show a great dependency on the distribution of the ocean currents, so that the distribution of the plankton is directly intelligible from the study of the great circular water movements. Steuer fully recognized that the study of the surface currents of the oceans can only provide an explanation of the distribution of those planktonic forms that inhabit the upper water masses, and that in order to understand the distribution of those species that live at depths greater than some 400–500 m., it is essential to study the movements of the intermediate currents, viz., the North Atlantic and Indian intermediate currents that tend to run from north to south and of the Sub-polar or Antarctic intermediate current that runs in the opposite direction from south to north, and for the inhabitants of the greatest depths, the Antarctic Bottom water.

So far as the surface currents are concerned, the lines along which these come in contact with each other are termed "Convergence lines" or, better, "Convergence zones," and it must be recognized that, though these are shown on charts as lines, this is merely a convenient schematic way of indicating their general position, and that actually where two such currents meet there is in fact between them a wide belt in which the surface water is moving in a complicated series of vortices ; such a condition is clearly shown in the chart given by Willimzik (1929, p. 23, fig. 6) of the portion of the South Indian Sub-tropical convergence to the south-east of Madagascar. Such vortices cause not only a very considerable degree of admixture of the water masses, but must also carry individuals belonging to different species of planktonic organisms from one mass of water into the other. It must also be recognized that these convergence lines on the surface of the ocean are merely the lines along which the planes, separating one great water mass from another, reach the surface, and that at different depths, where these planes separate one water mass from another, there is also a certain and perhaps a very considerable degree of admixture, that must carry with it some, at least, of the fauna.

In any given area, in which there is a more or less continuous current or series of currents at different depths, we should be able to correlate the distribution of the plankton with the movements of the water masses. Russell (1935, p. 6) has summed up the present position in the following words: "It is probable that in ocean waters one of the main barriers to distribution is that of the temperature conditions. Animals adapted for successful reproduction in any given temperature range will be carried in the water masses and ocean current systems so far as the necessary temperature conditions are maintained. When the temperature conditions have been taken into consideration, the chief clues to the geographical distribution of the species are to be found in the systems of oceanic circulation. . . . Each body of water has its own somewhat characteristic plankton fauna at different levels. These faunas tend to mix at the boundaries." In 1940 (Sewell, 1940*b*) I reviewed the evidence that we possess which indicates the extent to which planktonic organisms and to a less extent the neckton and benthos are influenced in their distribution by the various current systems in the three great oceans ; but, as Redfield (1941) has pointed out regarding the distribution of the plankton in the Gulf of Maine, in many species there is a marked diurnal migration that carries the plankton from one particular layer to another and "consequently the population cannot be identified exclusively with any particular layer, and any attempt to correlate its distribution with the drift of the water is complicated by the undoubted migration of the animals to and from layers of different depth moving with different velocities and in some places without doubt in different directions."

Earlier workers seem to have been impressed somewhat unduly by the degree of similarity between the faunas of the various regions, and especially of the faunas of the tropical and temperate regions of the three great oceans. Giesbrecht (1892) stated that from the knowledge that we then possessed it seemed clear that the faunas of the oceans differ but little from each other in comparison with the marked differences that are found between the faunas of the warm regions and those of the north or south cool areas. F. Dahl (1894) pointed out that the surface-living Copepoda of the tropical regions of the Indo-Pacific Ocean are for the most part the same owing to the free intercommunication that exists between the Indian and west Pacific regions by means of the surface currents ; and Bedot (1909) put forward the view that eupelagic marine animals can circulate freely throughout the whole hydrosphere, allowing themselves to be swept along by the currents, and that such differences as have been found to exist between the epi-pelagic fauna of different regions are only temporary. Steuer (1910), commenting on the work that had up to then been done in the great oceans, remarked that in spite of the comparatively

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little that had at that time been achieved in the Indian and Pacific Oceans, "the few observations already allow us to see that both in the Poles and on the Equator a uniform plankton, almost without exception, animates all seas," and he adds that in all areas the number of universally present species increases importantly with the progressive exploration of the high-sea Plankton.

Lohmann (1916) appears to hold the same view as Bedot, for he concludes that a species can live in all oceans and in all latitudes but that it can prosper only in warm water; and Steuer (1933) also appears to agree with this, for he considers that all the various regions and sub-regions into which he has divided the oceans only represent places of optimum conditions and temporary maximal development, and thus are to be regarded merely as regions of plenty, whereas those regions, in which a species has not as yet been taken, are regions of scarcity. He concludes that tropical species may be carried into the Antarctic and that, on the other hand, Antarctic species may be swept by the Antarctic deep currents into the tropical region, and that oceanic plankton may be carried downward into deep water and be transported by the deep currents to great distances; as a result of this he suggests that it may be necessary to compile distribution charts of individual species, not for the whole surface area of the ocean but for each depth-horizon separately, and in his study of different races within the limits of the same species he has indicated that in certain instances it is possible to correlate their occurrence with a particular deep current, as, for instance, he has shown to be the case with two varieties of *Pleuromamma xiphias* (Giesbr.), in which there is a small, warm-water form in the tropical region and a large, cold-water form that inhabits the West Wind Drift; but in the Arabian Sea both races occur, the large form having been carried northwards into the area at a depth of some 700 m. by the Antarctic intermediate current.

INTRODUCTION.

It is customary to subdivide the Copepoda into a series of groups according to the frequency of their occurrence and the increased numbers of individuals present in different habitats. These groups as given by Farran (1920) are (1) *Neritic* species, that are taken in large numbers near the coast; (2) *Oceanic* species, that are usually taken away from the coast in the open waters of the ocean; (3) *Euryhaline* species, that appear to have a wide tolerance to differences of salinity and so may be present in any locality, whether oceanic or littoral; and (4) *Benthic* species, that live on or close to the sea bottom.

Ostenfeld (1931) makes a more detailed subdivision and recognizes (1) Brackish-water species; (2) Littoral and brackish-water species; (3) Neritic, low salinity, species; (4) Neritic species; (5) Atlantic Oceanic species, existing all the year round under neritic conditions; and (6) Atlantic Oceanic species, existing for only part of the year in neritic conditions. F. Dahl (1894*a*) has however pointed out that, although it is possible to recognize a coastal zone as distinct from the general oceanic region, "many coastal forms occur in isolated instances in the high seas and similarly many oceanic forms occur on the coast." Russell (1935) has pointed out that some species coincide with the limits of certain water masses, while others spread over a wide area; and thus we get an overlap between species that can be classified in one or more groups. It must therefore be borne in mind that any such division is not a hard and fast one: a species may, as a rule, be abundant near the coast and so be classed as " neritic," and yet it may be quite capable of living and reproducing, though perhaps only in small numbers, in the open ocean. Steuer (1933*a*, p. 274) remarks, " Some neritic species are confined solely to the coast, others pass, for instance in the North Atlantic, far out into the open sea." Personally I very much doubt whether " neritic " species are so rigorously confined in their habitat. Indeed it not infrequently happens that a species is regarded by one author as " neritic " and by another as " oceanic " ; for instance, *Calanus finmarchicus* (Gunn.) is listed by Farran (1920, p. 16) as a neritic species, but the work of Sars and others has shown that it may be taken all over the North Atlantic Ocean, though frequently at considerable depths. *Pseudocalanus elongatus* (Boeck) is another species that is classed as neritic by Farran (1920) but was regarded as oceanic by Herdman and A. Scott (1912), and *Candacia armata* Boeck (= *C. pectinata* Brady) is such another. *Centropages hamatus* (Lillj.) and *Acartia discaudata* (Giesbr.) are usually taken in inshore waters and so would be classed as " neritic," but Herdman, Thompson and A. Scott (1898) have recorded both these species from the open waters of the mid-Atlantic, and the same is true of *Temora longicornis* (Müll.). *Anomalocera patersoni* Templ. on the other hand is listed as an " oceanic " species by Herdman, Thompson and A. Scott and as a euryhaline species by Farran, yet the chart of its distribution (*vide* Steuer, 1933*a*, p. 276) shows that as a rule it is taken in the vicinity of the coast and especially of the eastern shores of the north Atlantic. Farran (1936) has given a list of species that were taken on the Australian Barrier Reef and that he considers to be " coastal " in their habitat. There are 30 Calanoid species in this list, the names of which I give below :

Canthocalanus pauper Giesbr.
Undinula vulgaris (Dana).
Eucalanus subcrassus Giesbr.
Paracalanus aculeatus Giesbr.
P. parvus (Claus).
Acrocalanus gibber Giesbr.
Clausocalanus arcuicornis (Dana).
Calocalanus pavoninus Farran.
Undinopsis tropicus Wolfend.
Euchæta concinna Dana.
Scolecithrix danæ (Lubb.).
Centropages furcatus (Dana).
C. gracilis (Dana).
C. orsinii Giesbr.
Temora discaudata Giesbr.
Candacia æthiopica Dana.
C. discaudata A. Scott.
Calanopia elliptica (Dana).
Labidocera acuta (Dana).
L. acutifrons (Dana).
L. detruncata (Dana).
L. lævidentata (Brady).
Pontella cristata Krämer.
P. danæ Giesbr.
P. fera Dana.
Pontellopsis krameri (Giesbr.).
P. macronyx A. Scott.
P. regalis Dana.
Acartia pacifica Steuer.
Tortanus gracilis (Brady).

But of these 30 species as many as 19 have been taken in open water well out in the Arabian Sea or further south in the Indian Ocean. Farran (*loc. cit.*, 1936) also gives a list of " open sea " species, which includes the names of 38 species that are normally taken at or near the surface, namely :

Calanus tenuicornis Dana.
Neocalanus gracilis (Dana).
Nannocalanus minor (Claus).
Undinula darwini (Lubb.).
Eucalanus crassus Giesbr.
E. mucronatus Giesbr.

Rhincalanus cornutus (Dana).
Mecynocera clausi Thompson.
Paracalanus denudatus Sewell.
Acrocalanus gracilis Giesbr.
A. longicornis Giesbr.
A. monachus Giesbr.
Clausocalanus furcatus (Brady).
C. farrani Sewell.
C. paululus Farran.
Calocalanus plumulosus (Claus).
Euchæta consimilis Farran.
E. longicornis Giesbr.
E. media Giesbr.
E. wolfendeni A. Scott.
Scolecithrix danæ (Lubb.).
Centropages calaninus (Dana).
Temora turbinata (Dana).
Lucicutia flavicornis (Claus).
L. ovalis Wolfend.
Candacia bispinosa Claus.
C. catula Giesbr.
C. curta Dana.
C. longimana Claus.
C. simplex Giesbr.
C. truncata Dana.
Calanopia aurivillii Cleve.
Labidocera minuta Giesbr.
Pontella securifer Brady.
Pontellina plumata Dana.
Acartia danæ Giesbr.
A. negligens Dana.
A. pietschmani Pesta.

But of these species that are "open sea" forms in the Australian region, 28 have been taken on the Ceylon Pearl Banks, 19 in the enclosed waters of Nankauri Harbour in the Nicobar Islands and 16 in inshore waters on the South Burma Coast, and several species occur in all three localities; in all, 35 species out of the total of 38 have been captured in the littoral zone in the Indian Ocean.

In Indian waters some 74 species of Calanoids have up to the present time been taken only in areas that are essentially littoral in character, namely:

*_Paracalanus crassirostris_ Dahl.
*_P. dubia_ Sewell.
P. nudus Sewell.
P. nanus Sars.
*_P. serratipes_ Sewell.
Acrocalanus gardineri Wolfend.
*_A. inermis_ Sewell.
Calocalanus styliremis Giesbr.
C. contractus Farran.
Macandrewella chelipes (Giesbr.).
M. scotti Sewell.
Scolecithrix danæ (Lubb.).
Scolecithricella nicobarica Sewell.
S. pearsoni Sewell.
*_Centropages alcocki_ Sewell.
C. dorsispinatus Thomp. and A. Scott.
C. elongatus Giesbr.
C. trispinosus Sewell.
C. tenuiremis Thomp. and A. Scott.
*_Pseudodiaptomus annandalei_ Sewell.
*_P. aurivillii_ Cleve.
*_P. binghami_ Sewell.
P. clevei A. Scott.
P. burckhardti Sewell.
*_P. hickmani_ Sewell.
P. masoni Sewell.
P. mertoni Früchtl.
P. salinus Giesbr.
*_P. serricaudatus_ (T. Scott).
*_P. tollingeræ_ Sewell.
*_Isias tropica_ Sewell.
Temora discaudata Giesbr.
*_Pseudocyclops obtusatus_ Brady and Robertson.
*_P. simplex_ Sewell.
Calanopia aurivillii Cleve.
C. herdmani Thomp. and A. Scott.
C. thompsoni A. Scott.
Candacia bradyi A. Scott.
C. catula (Giesbr.).
C. discaudata A. Scott.

✓ *Labidocera bataviæ* A. Scott.
**L. euchæta* Giesbr.
**L. gangetica* Sewell.
L. kröyeri (Brady) and its varieties.
L. lævidentata (Brady).
✓ *L. maduræ* A. Scott.
✓ **L. pavo* Giesbr.
L. pectinata Thomp. and A. Scott.
**Pontella andersoni* Sewell.
P. danæ Giesbr. and its varieties.
✓ *P. denticauda* A. Scott.
**P. investigatoris* Sewell.
P. princeps Dana.
Pontellopsis herdmani Thomp. and A. Scott.
P. krameri (Giesbr.)
✓ *P. macronyx* A. Scott.
P. scotti Sewell.
P. strenua (Dana).
**Acartia centrura* Giesbr.
**A. chilkaensis* Sewell.
A. danæ Giesbr.
**A. plumosa* T. Scott.
**A. spinicauda* Giesbr.
A. southwelli Sewell.
**Acartiella gravelyi* Sewell.
**A. kempi* Sewell.
**A. major* Sewell.
**A. minor* Sewell.
**A. sewelli* Steuer. ?
**A. tortaniformis* Sewell.
Tortanus barbatus (Brady).
T. forcipatus (Giesbr.).
T. gracilis (Brady).
T. tropicus Sewell.

Of the above species 29, marked with an *, appear to be inhabitants of brackish water; and, as one would expect, many such species possess a very high degree of adaptability to changes of salinity. Percival (1929) has shown that the European species *Eurytemora affinis* (Poppe) and *Acartia bifilosa* (Giesbr.) in the estuary of the Tamar River can survive in a range that extends from 0·1 to 33·0 ‰ and 0·3 to 32·0 ‰ respectively. Among the Indian species we also find a very considerable range of adaptability (*vide* Sewell, 1934, p. 110), the full extent of which has not yet been determined, but I give below the ranges of salinity that have been observed in some of these species in Indian waters:

Acrocalanus inermis Sewell	in salinity ranging from	0·17	to	33·0	‰
Labidocera euchæta Giesbr.	,, ,, ,,	2·0	,,	32·65	,,
Acartia spinicauda Giesbr.	,, ,, ,,	2·0	,,	32·06	,,
Pontella andersoni Sewell	,, ,, ,,	7·9	,,	32·97	,,
Paracalanus crassirostris F. Dahl	,, ,, ,,	10·0	,,	33·0	,,
Centropages dorsispinatus Thomp. and A. Scott.	,, ,, ,,	10·9	,,	32·82	,,
C. tenuiremis Thomp. and A. Scott.	,, ,, ,,	10·9	,,	32·66	,,
Labidocera pectinata Thomp. and A. Scott.	,, ,, ,,	10·9	,,	32·84	,,
Pseudodiaptomis aurivillii Cleve	,, ,, ,,	16·29	,,	32·84	,,
Candacia discaudata A. Scott	,, ,, ,,	16·29	,,	33·27	,,
Calanopia thompsoni A. Scott	,, ,, ,,	16·29	,,	33·27	,,

Among those species that are truly marine, though frequently taken in inshore waters, the range of adaptability is not quite so great. de Lint (1922) gives the range for *Centropages hamatus* (Lillj.) as extending in the Zuiderzee from 23·9 ‰ to as low as 13·5 ‰. A number of species, that are frequently taken in, and may be regarded as characteristic of, open water, have been captured in inshore waters on the South Burma coast, and here too there appears to be wide range of tolerance to differences of salinity :

Acartia centrura Giesbr.	in salinity ranging from	10·9	to	29·05	‰
Paracalanus aculeatus Giesbr.	,, ,, ,,	10·9	,,	36·35	,,
Undinula vulgaris (Dana)	,, ,, ,,	10·9	,,	36·35	,,
Labidocera minuta Giesbr.	,, ,, ,,	10·9	,,	36·50	,,
Metacalanus aurivillii Cleve	,, ,, ,,	16·29	,,	32·82	,,
Acrocalanus gibber Giesbr.	,, ,, ,,	16·29	,,	32·96	,,
Eucalanus subcrassus Giesbr.	,, ,, ,,	16·29	,,	36·35	,,
E. monachus Giesbr.	,, ,, ,,	16·29	,,	32·96	,,
Temora turbinata (Dana)	,, ,, ,,	16·29	,,	33·27	,,
Centropages furcatus (Dana)	,, ,, ,,	16·29	,,	33·27	,,
Macrosetella gracilis (Dana)	,, ,, ,,	16·29	,,	36·27	,,
Paracalanus parvus (Claus)	,, ,, ,,	16·29	,,	36·35	,,
Canthocalanus pauper Giesbr.	,, ,, ,,	16·29	,,	36·35	,,
Calanopia elliptica (Dana)	,, ,, ,,	16·29	,,	36·50	,,
Acartia erythræa Giesbr.	,, ,, ,,	28·48	,,	35·53	,,

Most of these latter species are of frequent occurrence in these inshore waters, and out of a total of 37 surface tow-nettings taken on the Burma coast in 1913–14, the species given below were identified the following number of times :

Paracalanus aculeatus Giesbr.	33	times.
Temora turbinata (Dana)	27	,,
Canthocalanus pauper Giesbr.	26	,,
Acrocalanus gibber Giesbr.	25	,,
Labidocera minuta Giesbr.	25	,,
Eucalanus monachus Giesbr.	22	,,
Centropages furcatus (Dana)	22	,,
Calanopia elliptica (Dana)	20	,,
Eucalanus subcrassus Giesbr.	17	,,
Acartia erythræa Giesbr.	14	,,
Undinula vulgaris (Dana)	10	,,
Metacalanus aurivillii Cleve	7	,,
Acartia centrura Giesbr.	7	,,
Macrosetella gracilis (Dana)	4	,,
Paracalanus parvus (Claus)	2	,,

Out of a total of some 60 surface-living species that have been taken off the South Burma coast the number of oceanic forms is 37, or 60 per cent. I have records of 66 species that have been taken in the region of Nankauri Habour, in the Nicobar Islands and of these 45 are known to occur in the open ocean, or 68 per cent. From the Ceylon Pearl banks 86 surface-living species are known, of which 58, or 64 per cent., are oceanic species. Finally from the Maldive and Laccadive Archipelagoes out of a total of 63 species 46, or 73 per cent., are known to occur in the open ocean. The increase in the percentage of oceanic forms in this latter area is only to be expected in view of its geographical situation, but the fact that around these coral islands, that have never been connected with the mainland, we still find as many as 27 per cent. of littoral forms equally clearly indicates that these forms must be able to traverse wide areas of open water.

A study of the distribution of the Copepoda compels one to realize that the vast majority of species, including not only those that are classed as neritic but also many of those that are to-day usually found to be inhabitants of brackish-water or estuarine regions, must be, or at some previous time have been, capable of surviving transportation from one inshore region to another and have been carried along by currents, either in-shore or off-shore, across areas that are to-day oceanic in character. Apart from a relatively few brackish-water forms, there are very few species that are confined to a single locality and many are of world-wide distribution ; and even in these brackish water species one is not justified in assuming that their habitat is so sharply localized until much more research has been carried out. That transportation in the past must have had far-reaching effects on the distribution and evolution of related species is indicated by the present-day distribution of the species of the genus *Pseudodiaptomus* (*sensu lato*), which, as is now generally accepted, was originally marine in its habitat, but has succeeded in invading brackish water in many parts of the world and has even become established in fresh water. Marsh (1933) has subdivided this genus into two closely related genera, *Pseudodiaptomus* Herrick (*sensu stricto*) and *Schmackeria* Poppe and Richard, but since the main character used to separate these two genera is to be found in the character of the 5th pair of legs in the male, it is not possible to refer to either genus those species in which only the female is at present known. In the genus *Schmackeria* the great majority of species are to day to be found living in fresh or brackish water, only a single species, *S. sericaudatus* (T. Scott), being truly marine, though this too may occur in brackish water, and having a wide distribution in both the Indian and Atlantic Oceans. As regards the other species that Marsh includes in this genus, we find *Schmackeria inopinus* Burckhardt and *S. forbesi* Poppe and Mrazek, both from fresh-water, in China ; *S. japonicus* Kikuchi, from fresh-water (?), in Japan ; *S. smithi* Wright from fresh-water (?), in the Philippine islands ; *S. poppei* Stingelin, from fresh-water, in Celebes ; *S. nostradamus* Brehm, from fresh-water, in Java ; *S. binghami* Sewell, in fresh- and brackish-water of the estuary of the Rangoon River, in Burma and the Chilka Lake, India ; *S. annandalei* Sewell and *S. tollingeræ* Sewell, in brackish-water, in the Chilka Lake, India ; *S. dubius* Kiefer, in fresh-water (?), at Vizagapatam on the east coast of India ; *S. lobipes* (Gurney) from fresh-water at Calcutta and from the Chilka Lake, in India ; and *S. cornutus* Nicholls, in brackish-water, from the south coast of Australia.

In the very closely related genus *Pseudodiaptomus* Herrick (*s. str.*) there are six, or possibly seven, species that are marine in their habitat, namely, *P. aurivillii* Cleve, *P. clevei* A. Scott, *P. mertoni* Früchtl and *P. salinus* Giesbr. from the Indo-Pacific region, and *P. pelagicus* Herrick from the Atlantic coast of North America and perhaps *P. americanus* Wright from the Gulf of Mexico. The remaining species are from either brackish- or fresh-water, namely *P. dauglishi* Sewell, from brackish-water (?), in Perak, Federated Malay States ; *P. hickmani* Sewell from the south-east coast of Australia (as a variety), and brackish-water of the Rangoon River estuary, in Burma ; *P. stuhlmanni* Poppe and Mrazek, from fresh-water, in East Africa ; *P. hessei* (Mrazek), from brackish-water in the Gulf of Guinea, West Africa ; *P. richardi* (Dahl) and *P. marshi* Wright, in brackish-water on the east coast of South America ; *P. acutus* (Dahl) and *P. gracilis* (Dahl) from brackish or fresh-water in the estuary of the Amazon River, South America; *P. cristobalensis* Marsh and *P. culebrensis* Marsh, both from fresh-water, on the east and west sides respectively of the Isthmus of Panama; and *P. coronatus* Wilson, from brackish- or salt-water in the Woods Hole region of the east coast of North America; and Johnson (1939) has described a new subgenus and species, *P.* (*Pseudodiaptallous*) *euryhyalinus* from brackish-water in South Carolina. In both these genera the ancestral forms must have become widely dispersed by means of currents that involved a passage from the Indo-Pacific region into the Atlantic Ocean.

A very similar distribution is to be found in the littoral-haunting species *Paracalanus crassirostris* F. Dahl, which has now been recorded from such widely separated localities as the Aru Archipelago (Früchtl); the sea off Penang and the mouth of the Karau River, Malaya, the Andaman and Nicobar Islands, the Chilka Lake, India (Sewell); the Pearl Banks of Ceylon (Thompson and A. Scott) and the estuary of the Amazon River, South America (Dahl); while closely related forms or varieties have been evolved in other areas, such as *P. crassirostris* f. *sewelli* Früchtl (= *P. dubia* Sewell) in the Rangoon River estuary, Burma, and *P. crassirostris* f. *scotti* Früchtl (= *P. pygmæus* T. Scott, non Claus) in the Gaboon River and Congo River estuaries in the Gulf of Guinea. Here again the only possible explanation appears to be that of dispersal of the ancestral form by the agency of marine currents, followed by evolution into forms or races in certain localities as a result of differences in the local conditions; and if one accepts the theory of the permanence of the ocean basins, one stage of the journey that may have taken several generations to accomplish must have been across the whole width of the South Atlantic Ocean.

A study of those species that are usually classed as oceanic and benthic reveals that these must be divided into two quite distinct groups. Schott (1935, p. 331) has called attention to the fact that there is a marked and progressive falling off in the total number of planktonic organisms as one passes from the surface down to the greatest depths, and I reproduce below the table that he gives for the Atlantic Ocean:

Depth in m.	Number of individuals per litre.
0	10,147
50	9,443
100	2,749
200	726
400	216
700	114
1000	87
2000	57
3000	18
4000	17
5000	15

Schott maintains that conditions are very similar in all three oceans, and that such local differences as do occur are of comparatively small importance. In the case of the pelagic Copepoda, however, the results obtained by a number of expeditions seems to indicate clearly that this gradual fall in the number of either individuals or species is conspicuous by its absence. In the results obtained by the "John Murray" Expedition the approximate numbers of individuals of the Copepoda at different depths are as follows:

Depth in metres.	Number of individuals captured.
100–0	>6503*
200–100	601
300–200	220
400–300	728
500–400	1423
600–500	5643
1000–850	3103
1500	341
2000	24
2800	2

These results can only be regarded as approximate since the greater number of hauls were not made with a self-closing net and in consequence the net was fishing all the way from its greatest depth to the surface; but as in nearly all the hauls the net was towed, so far as could possibly be managed, horizontally for an hour and was then hauled to the surface, it is justifiable to assume that the greater part of the catch was made at the depth of the horizontal part of the haul, and I have taken the figures of each catch as representing the number of individuals present at that depth. Clearly there are two very distinct maxima in the density of the population, one at or near the surface between 100 and 0 m., and a second at a depth of about 600 m., with an intervening minimum at 300–200 m. depth.

Similarly, if we consider the number of species represented in the various catches we reach the same conclusion. In the upper levels at or near the surface the "John Murray" Expedition captured 109 species of epi-planktonic forms. Although it is not possible to give with any degree of certainty the lower limit of occurrence of any of the deep-sea species, since we were only very rarely able to use a self-closing net, it is possible to give the depth below the surface at which, apart from stray individuals, each species first makes its appearance.

At 100 m. depth 9 species were taken, namely:

Calanoides patagoniensis Brady (juv.).
Eucalanus attenuatus (Dana).
E. pseudattenuatus sp. nov.
Rhincalanus nasutus Giesbr.
Undeuchæta bispinosa Esterly (juv.).
Euchirella galeata Giesbr. (juv.).
E. bella Giesbr.
Scottocalanus dauglishi Sewell.
Pleuromamma quadrungulata Wolfend.

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* In the case of several of the more common species the numbers present were not actually counted, and they were merely classed as "numerous.

At 200 m. 9 other species have been taken, namely :

Eucalanus elongatus (Dana).
Euchirella orientalis Sewell.
E. pulchra (Lubb.).
Euchæta tenuis Esterly.
Heterorhabdus spinifrons (Claus).
Pleuromamma abdominalis (Lubb.) (juv.).
P. xiphias Giesbr.
Euaugaptilus nodifrons Sars.
Arietellus giesbrechti Sars.

At 300 m. we get 7 other species, namely :

Gætanus miles Giesbrecht.
G. latifrons Sars.
Chirundina indica Sewell.
C. streetsi Giesbr. (juv.).
Pseudochirella magna (Wolfenden) (juv.).
Undeuchæta bispinosa Esterly (adult).
Scottocalanus helenæ (Lubb.).

At 400 m. 11 species were taken for the first time :

Gætanus pileatus Farran.
Euchirella galeata Giesbr. (adult).
E. truncata Esterly.
Paraeuchæta investigatoris Sewell.
P. weberi A. Scott.
Scottocalanus securifrons (T. Scott).
Scaphocalanus magnus (T. Scott).
Heterorhabdus abyssalis (Giesbr.).
Metridia princeps Giesbr.
Pleuromamma indica Wolfend.
P. abdominalis (Lubb.) (adult).

At 500 m. depth 14 more species have made their appearance :

Neocalanus gracilis (Dana).
N. robustior (Giesbr.).
Paræuchæta scotti (Farran).
Megacalanus princeps Wolfend.
Scottocalanus persecans (Giesbr.).
Lophothrix frontalis Giesbr.
Heterostylites longicornis (Giesbr.).
Haloptilus chierchiæ Giesbr.
H. mucronatus (Claus).
H. ornatus (Giesbr.).
H. oxycephalus (Giesbr.).

Lucicutia magna Wolfend.
Augaptilus longicaudatus (Claus).
Copilia hendorfii M. Dahl.

At 650–600 m. we get the appearance of 16 more species :

Bradycalanus sp. (juv.).
Gætanus kruppi Giesbr.
Euchirella maxima Wolfend.
Paraeuchæta sarsi Farran.
P. tonsa (Giesbr.).
Onchocalanus trigoniceps Sars (juv.).
Amallothrix indica Sewell.
Lucicutia challengeri Sewell.
Mesorhabdus angustus Sars.
Disseta palumboi Giesbr.
Euaugaptilus magnus (Wolfend.).
Haloptilus acutifrons (Giesbr.).
H. validus Sars.
Heteroptilus acutilobus Sars.
Arietellus simplex Sars.
A. plumifer Sars.

And with this group we may include *Pseudochirella magna* (Wolfend.) (adult) that was captured in a haul from 645–400 m. At 850 m. depth we get as many as 23 species making their first appearance, namely :

Gætanus brevicornis Esterly.
G. minor Farran.
Euchæta spinosa Giesbr.
Paraeuchæta malayensis Sewell.
P. spinifera Esterly.
Onchocalanus affinis With.
O. trigoniceps Sars.
Xanthocalanus greeni Farran.
Lophothrix quadrispinosa Wolfenden.
Amallothrix arcuata Sars.
A. emarginata (Farran).
A. gracilis Sars.
Gaussia princeps (T. Scott).
Euaugaptilus elongatus Sars.
E. facilis (Farran).
E. indicus Sewell.
E. laticeps Sars.
E. latifrons Sars.
E. longicirrhus Sars.
E. longimanus Sars.
E. oblongus Sars.
Hemirhabdus truncatus (A. Scott).
Pachyptilus eurygnathus Sars.

And with this group we may include *Centraugaptilus horridus* (Farran) that was first taken at 1000 m. depth.

At 1500 m. depth we again get 24 fresh species :

? *Bathycalanus bradyi* (Wolfend.) (juv.).
Calanus finmarchicus Gunn.
Gætanus curvicornis Sars.
G. antarcticus Wolfend.
Euchirella venusta Giesbr.
Pseudochirella notacantha Sars.
P. obtusa Sars.
Undeuchæta major Giesbr.
Pseudeuchæta brevicauda Sars.
Paraeuchæta bisinuata Sars.
P. withi sp. nov.
Valdiviella oligarthra Steuer.
Lophothrix humilifrons Sars.
Hemirhabdus grimaldii (Richard).
Lucicutia bicornuta Wolfend.
Euaugaptilus angustus Sars.
E. bullifer (Giesbr.).
E. digitatus Sars.
E. grandicornis Sars.
E. penicillatus Sars.
E. tenuispinus Sars.
Pachyptilus lobatus Sars.
Phyllopus impar Farran.
P. muticus Sars.

Below this depth we get an extremely rapid reduction in the number of species that make their first appearance. At 2000 m. depth we get only two, namely :

Paraeuchæta hanseni (With).
Valdiviella insignis Farran.

At 2500 m. depth we get only one fresh species making its first appearance, namely :

Bathycalanus bradyi (Wolfend.) (adult).

And finally at 2926 m. depth we again get only one :

Bradycalanus gigas sp. nov.

If now we arrange these numbers in tabular form, as follows :

Depth in metres.	Number of species first taken at this depth.
0	109
100	9
200	9
300	7
400	11
500	14
600–650	16
850–1000	24
1500	24
2000	2
2500	1
2926	1

it seems clear that with increasing depth there is a gradual increase in the number of deep-sea species and that the maximum in this region of the Indian Ocean is to be found at about 850–1500 m., and that below this there is a very rapid reduction in the number. It will also be noted that in several species young forms have been taken at a considerably higher level than the adults.

An analysis of the catches obtained by previous expeditions yields very similar results. In the collections made by the " Investigator " in the Bay of Bengal and Laccadive Sea (*vide* Sewell, 1929 and 1932) 138 warm-water epi-planktonic species were obtained : in the deeper levels at 366 m. (200 fms.) 45 deep water species were taken ; at about 732 m. (400 fms.) 21 of these species had disappeared but 30 others had made their first appearance, thus making a total of 54 species in all at this depth ; and at 1280 m. (700 fms.) 38 of these 54 had disappeared but 54 others had taken their place, so that the total number of species recorded from this depth was 70. As in the " John Murray " Expedition, the nets were towed for about an hour at or near the given depth and were then hauled to the surface fishing all the way up, but it is assumed that the greater number of each species in these hauls came from the depth given. Damas and Koefoed (1907) have given the following results for the area between Spitzbergen and Greenland in about lat. 75° N. :

Depth in metres.	Number of species present.
0–20	6
20–100	11
100–200	13
200–500	15
500–1000	17
Over 1000	21

Wolfenden (1904) has given tables of the numbers of species obtained by him in the North Atlantic Ocean and the Faroe-Shetland channel in different degrees of latitude between 50° and 61° N., and if we take the average of all the data we get the following result :

Depth in metres.	Number of species captured.
0	5
183	9
366	10
549	16
732	12
914	12
1097	8
1280	8
1463	8
1829	7
2195	9

and Wolfenden remarks that ' it is not unfair to conclude from these data that the greater number of species of Copepoda in the North Atlantic prefer a mesoplanktonic existence between 200–500 or 600 fathoms (366–914 or 1097 m.) depth " ; the greatest number are apparently to be found at about 550 m. Thompson (1903) at three stations in deep water to the west of Ireland has given the following figures :

Depth in metres.	Number of species present.		
	Lat. : 52° 27·5′ N. Long. : 15° 40′ W.	52° 18′ N. 15° 53′ W.	52° 20′ N. 15° 7·9′ W.
0	6	5	..
100–200	..	..	4
200–300	..	..	8
300–400	..	..	8
400–500	..	..	2
500–600	..	16	17
600–700	..	..	11
700–800	5	19	..
900–1000	10	21	..
1000–1100	17	32	..
1100–1200	20	21	..
1300–1400	12	19	..
1400–1500	16	24	..
1500–1600	22	25	..
1600–1700	24	20	..
1700–1800	6	14	..

It seems probable that in this region there are two maxima at different depths, the first occurring at about 1000–1200 m. depth and the second at 1500–1700 m. depth. It seems possible that this double maximum is associated with the presence of more than one layer of water ; Wüst (1936) gives a figure showing the depth distribution of the various water masses that compose the Atlantic Intermediate water, and in these northern latitudes we seem to have the " North Atlantic upper deep water " at about 1000 m. depth, and in continuity with this is the outflowing Mediterranean water ; immediately below this lies the "North Atlantic middle deep water." Farran (1926) has given the results obtained by the "Research" in the Bay of Biscay; in this collection a series of vertical hauls were made with self-closing nets, and Farran has made a careful analysis of the numbers of species and the average number of specimens taken at the different levels, which I reproduce below:

Depth in metres.	Depth in fathoms.	Number of hauls.	Total number of species.	Average number of specimens per 100 fms. (183 m.).
274–91	150–50	1	20	515
274–183	150–100	1	17	164
366–183	200–100	6	47	425
457–274	250–150	3	43	781
549–366	300–200	3	44	522
732–549	400–300	3	50	373
914–732	500–400	3	57	296
1372–914	750–500	4	66	232
1820–1372	1000–750	3	65	245
2286–1829	1250–1000	2	22	78
2743–2286	1500–1250	1	14	88
3658–2743	2000–1500	1	11	4·6

In this series the greatest number of specimens occurs at a depth of 274–91 m. or at 457–274 m., with an intervening minimum at 274–183 m.; but the greatest number of species occurs at a depth of about 1372 m. T. Scott (1894) in a series of tow nettings at different depths in the Gulf of Guinea in lat. 1° 55′ 5″ N., long. 5° 55′ 5″ E. obtained the following results:

Depth in metres.	Number of species captured.
0	21
55	44
110	15
293	19
476	26
658	47
841	28

In the collections made by the "Siboga" in the Malay Archipelago (*vide* A. Scott, 1909) an analysis of the various catches indicates that about 150 warm-water epi-planktonic species were taken, and in the deeper levels the number of species captured in the various hauls are as follows:

Depth in metres.	Number of deep-sea species taken.
200–0	8
750–0	69
900–0	43
1000–0	80
1500–0	79
2000–0	39

In this region we thus appear to have two maxima, the upper at a depth of about 750 m. and a second at about 1000 m., and it is interesting to note that in the upper group at 700–750 m. depth there are 13 species that do not occur at the lower level, while in the lower group at 1000–2000 m. depth there are as many as 55 species that were not taken in the upper strata, which strongly suggests that we are here dealing with two different masses of water. A somewhat similar condition was found in the North Atlantic Ocean by Leavitt (1938) in the western region. Leavitt attributes this phenomenon to the different conditions existing in two superposed water masses of different origin. If we consider the number of species taken at different depths in the various basins of the Malay Archipelago we get the following results :

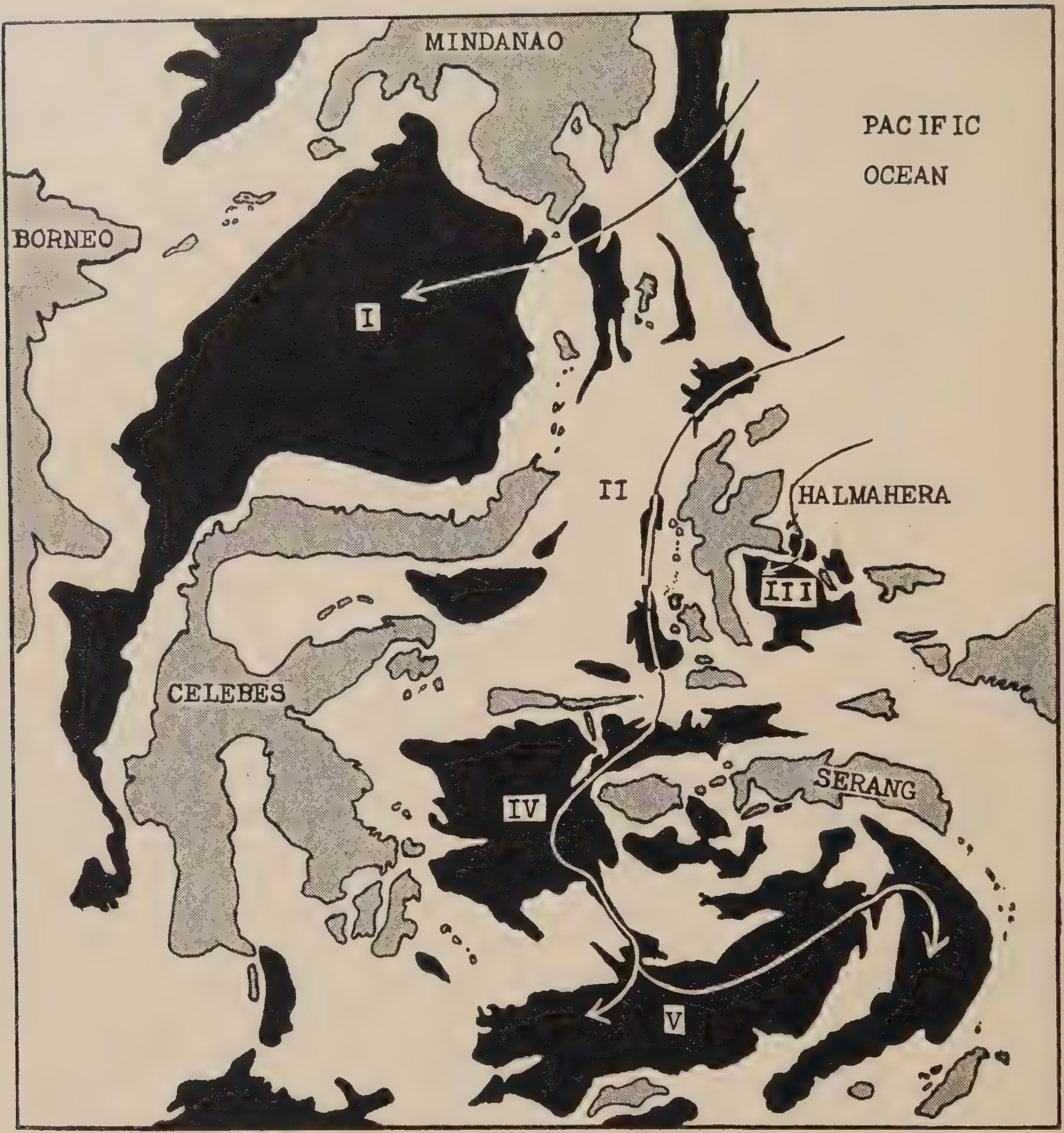
Depth in metres.	Celebes Sea.	Halmahera Basin.	Molucca Passage.	Total.	Banda Basin.
200–0	..	..	..	..	8
475–415	..	..	..	..	7
700–0	38	..	..	38	..
750–0	..	..	..	..	59
900–0	43	..	..	43	..
1000–0	..	72	..	72	34
1500–0	..	..	65	65	61
2000–0	..	..	..	..	38

It thus appears that in the region of the Celebes Sea, Halmahera Basin and the Molucca Passage there is a single maximum situated at a depth of about 1000 m., but in the Banda Basin there seems to be two maxima at about 750 and 1500 m. respectively. van Riel (1938) has shown that the deep water of the Celebes and Halmahera Basins (Text-fig. 72) enters directly from the Pacific Ocean, whereas the inflowing water in the Banda Basin has passed successively through, first, the Morotai Basin and the Ternate Trough, and then on from the Batjan Basin through the Boeroe Basin into the Banda Basin, and that this deep water enters the Banda Basin at a depth of about 1500 m. : he has given a diagram to illustrate this (van Riel, 1938, Pl. II), though he specifically warns the reader that the arrows in the diagram, which I reproduce below (Text-fig. 73), must not be interpreted as stream lines. It thus appears probable that the lower maximum in the Banda Basin is correlated with this inflowing deep water.

The report by Vervoort (1946) on the Copepoda of the "Snellius" Expedition in the eastern part of the Netherlands East Indies gives a similar result :

Depth of haul.	Number of species taken.
200–0	4
500–0	9
1000–0	12
1500–0 2000–0	9
2500–0	8
3000–0 4000–0	5

In this collection the maximum number of species was taken at a depth of about 1000 m.



Text-fig. 72.—Sketch Map showing the deep basins of the Malay Archipelago. I. Celebes Sea. II. Molucca Passage. III. Halmahera Basin. IV. North Banda Basin. V. South Banda Basin.

Again, an analysis of the results obtained by the "Terra Nova" (*vide* Farran, 1929) shows that in the New Zealand area of the Pacific Ocean 69 species belonging to the warm-water surface-living group were taken, but that as we pass further southwards the number of these rapidly falls off, and in latitudes higher than 60° S. the number of cool-water, deep-dwelling forms shows a marked tendency to occur on or near the surface. Thus in lats. 30°–40° S. to the north of New Zealand, while still in the sub-tropical region, the "Terra Nova" captured at or near the surface as many as 117 species, but of these 69 were warm-water epi-planktonic forms, the remaining 48 being such as are usually taken in the tropics in greater depths. Still further south, in lats. 50°–60° S., within the region of the West Wind Drift, 40 species were taken in the upper 40 m., but of these only 12 were warm-water, epi-planktonic forms and 28 were cool-water, deep-dwelling species that occur in the lower strata in the tropical region. In the true Antarctic region, south of lat. 60° S., only 5 warm-water epi-planktonic species were captured; here the numbers of species that were taken at the different levels were as follows:

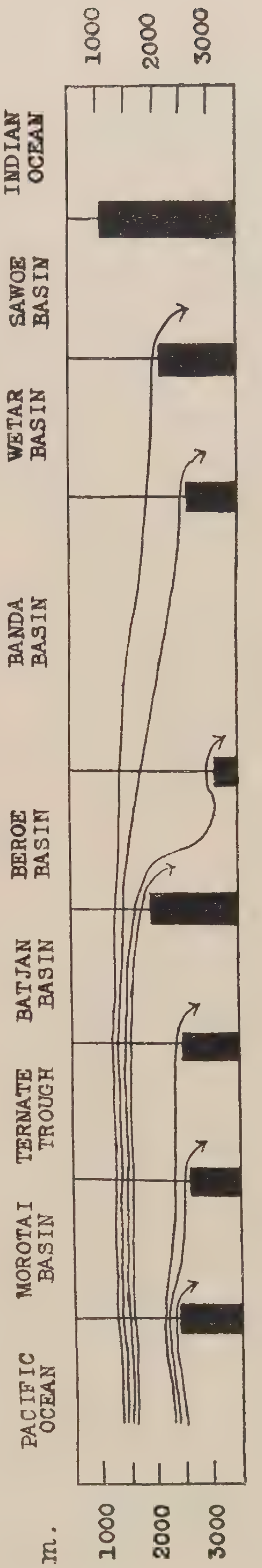
Depth in metres.	Number of species captured.
100–0	30
150–120	6
200–150	4
300	3
450–400	7 (? 8)
500	7
600	11
1000	31
1750	20

Here again we get a clear indication of two maxima in the number of species present, namely, at 100–0 m. and 1000 m. respectively.

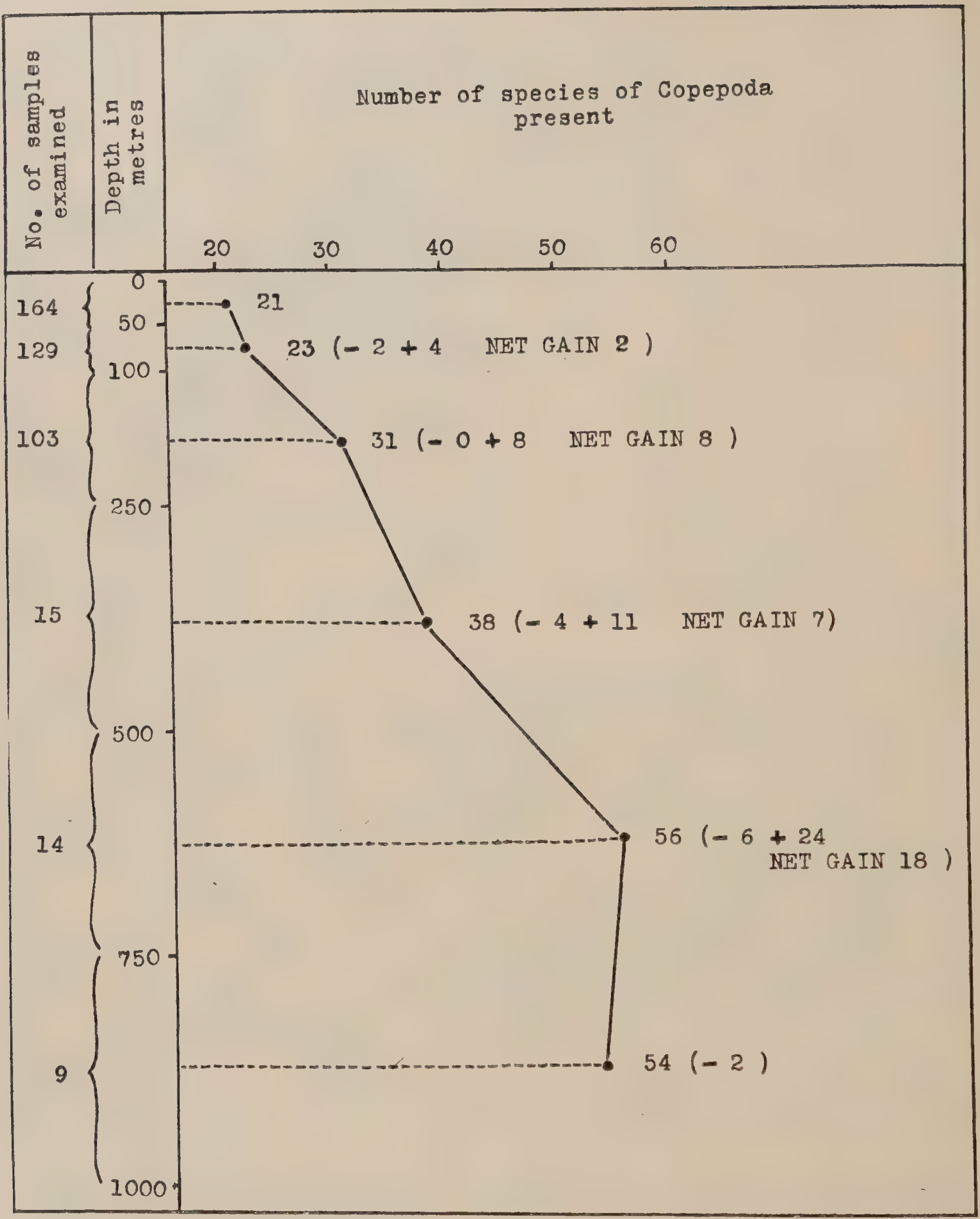
In the "Discovery" collections from the Antarctic (*vide* Hardy and Gunther, 1935) there appears to be a steady increase in the total number of species present as we pass downwards from the surface, the maximum being reached at about 600–700 m. I reproduce overleaf the curve, drawn by Mr. Andrew Scott, that these authors have published of the number of species of Copepoda taken at different depths (Text-fig. 74).

A very similar result was obtained by the "Gauss" in the Indian Region of the Antarctic Ocean (*vide* Wolfenden, 1911). In this collection the number of species taken at different depths was as follows:

Depth in metres.	Number of species taken.	Tropical species.	Antarctic species.
100	4	1	3
150	12	2	10
350–400	25	10	15
1200	35	14	21
2000	26	10	16
3000	25	10	15
3423	11	3	8



TEXT-FIG. 73.—Indicating the direction of flow of the bottom water from the Pacific Ocean into the various basins of the Malay Archipelago. (From P. M. van Riel, 1938.)



Text-fig. 74.—Curve showing the increasing number of species of Copepoda with increasing depth in the South Georgia region of the Antarctic zone. (From Hardy and Gunther.)

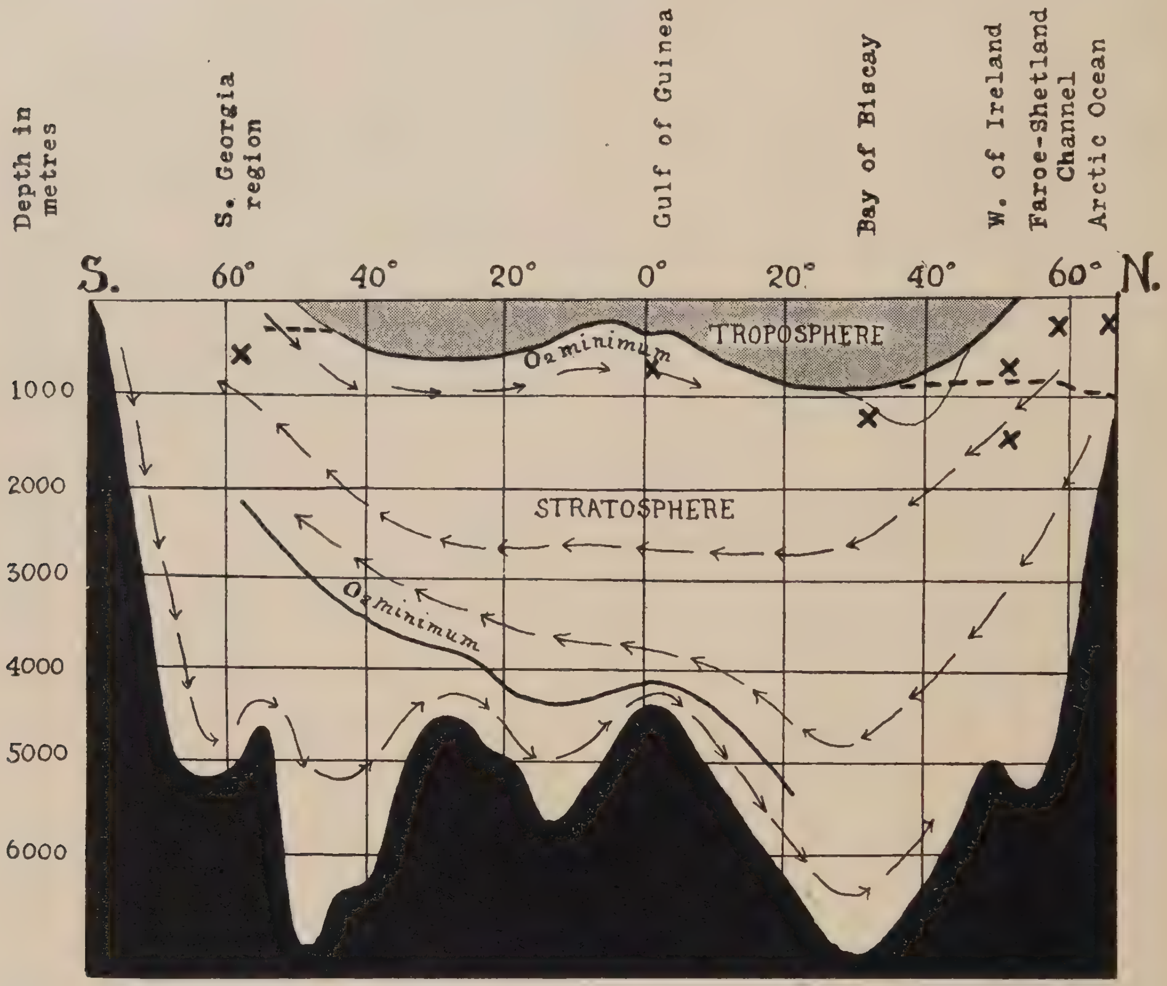
In this area the greatest number of species occurs at a depth of about 1200 m. As Hardy and Gunther (1935, p. 121) have pointed out, " it would appear that only a limited number of species have been able to adapt themselves to the conditions of the cold Antarctic surface layer " ; and, furthermore, it seems equally true that the maximum number of so-called Antarctic species is to be found at the same depth and in the same water mass as that in which occurs the main influx of tropical species into the Antarctic region.

The available evidence thus points to the conclusion that the planktonic Copepoda as a whole can be divided into two main groups, (1) those that inhabit the warm upper stratum of the tropical and sub-tropical regions, for the most part in the 100–0 m. stratum, and (2) those that inhabit the cool, deep-water stratum and have an optimum at a depth that may vary in different regions, but falls between 550 and 1200 m. depth; but no hard and fast line can be drawn between these two groups, for some species that are normally to be found in the upper warm layer may be carried down into deeper levels and thus be taken with the cold-water, deep-dwelling forms, and, conversely, some of the deep species may be brought by upwelling currents to, or near to, the surface, and thus be taken alongside the warm-water forms, while representatives of both groups may be carried into the cold water of the surface layer in the Arctic and Antarctic regions. F. Dahl (1894*a*) put forward the view that the pelagic Copepoda could be divided into three groups, namely, an upper group that inhabits the stratum from the surface down to 100–200 m., a middle group inhabiting depths between 200 and 1000 m., and lastly, a deep group living below 1000 m. depth. Defant, in a paper published in 1928, divided the oceans into three strata, namely an upper warm-water layer that is found only in the tropical and sub-tropical regions, and to which he gave the name "Troposphäre" and the uppermost layer of which he designated the "Störungzone," and a deeper cold-water layer, the "Stratosphäre," that includes the deep water of the ocean basins and the water of the two Polar regions. He gave the approximate depths of these layers, as follows:

"Störungzone," from 0 to about 200 m.
Troposphere, ,, 200 ,, ,, 1300 m.
Stratosphere, ,, 1300 ,, the bottom.

One might thus be tempted to correlate each of Dahl's groups with one of the three strata into which Defant has divided the ocean; thus Dahl's first group might be regarded as inhabitants of the "Störungzone," the middle group of the deeper layer of the Troposphere and, lastly, the third, deep-dwelling group as belonging to the Stratosphere. But the above results do not bear this out, and although certain species are to be found for the most part, if not exclusively, in the deepest levels, these cannot be separated off as a distinct group. In a later paper, however, Defant (1930) puts the thickness of the upper stratum, including both the "Störungzone" and the rest of the Troposphere, as not greater than 400–500 m. Wüst (1936) claims that between lat. 45° S. and lat. 53° N. in the North Atlantic Ocean lies a layer of warm water, namely the Troposphere, having an average depth of about 500 m., and, if we accept this estimate, then the two groups of the oceanic Copepoda will coincide respectively with the Troposphere and the Stratosphere.

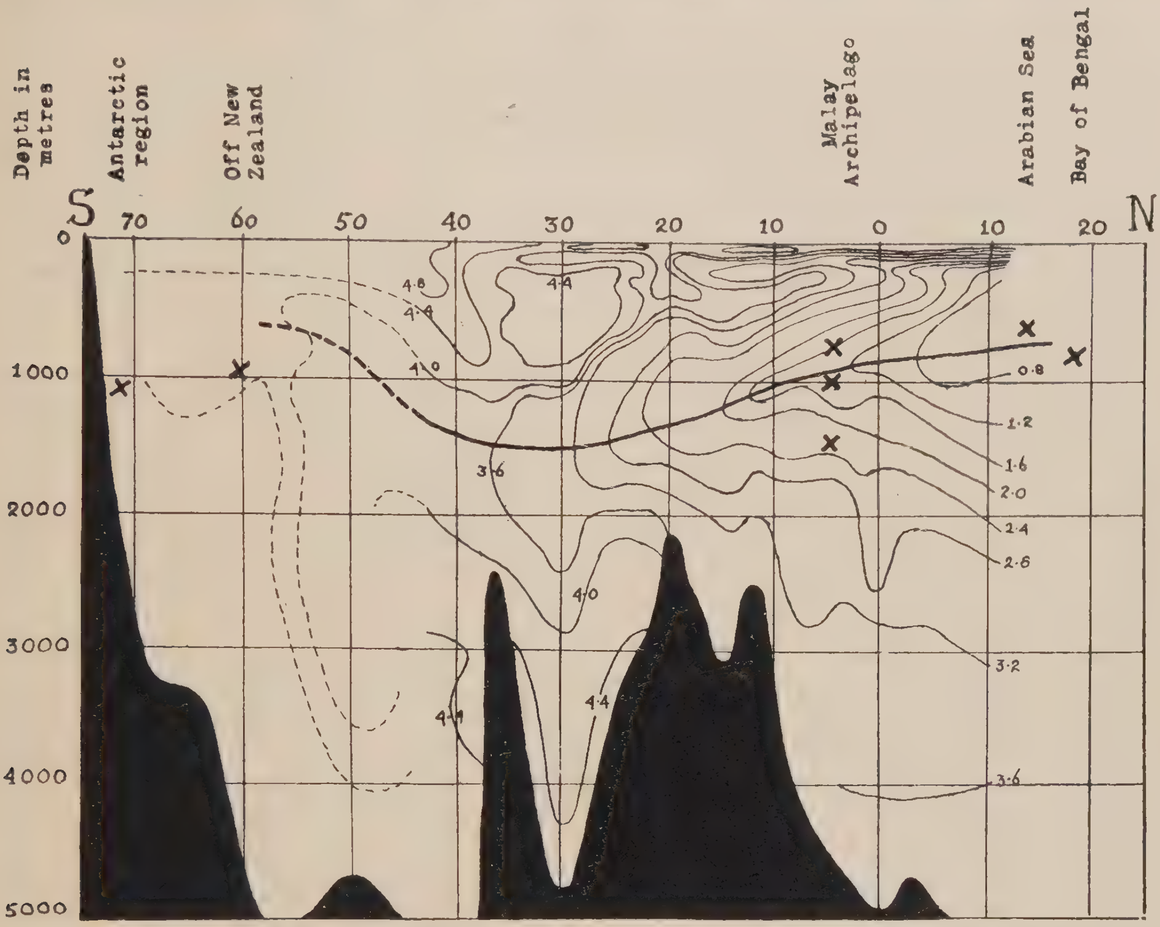
Wüst further suggests that the boundary between the Troposphere and the Stratosphere below it "is best characterized by the intermediary principle minimum of oxygen, which may be traced from 45° S. to 55° N., and which for the most part coincides approximately with the isotherm of 8° C." Although the depth at which we find the maximum number of deep-sea species in the Copepoda varies somewhat in different regions, in every case it falls between 550 and 1200 m., and a comparison of these depths with the depth of the minimum oxygen concentration shows a very considerable degree of agreement. In the two figures given below I have plotted the position of the maximum concentration of the Copepoda on the chart of minimum oxygen in the Atlantic (Text-fig. 75) and the Indian (Text-fig. 76) Oceans, and on this latter I have also given the maximum concentration of the Copepoda in the Malay Archipelago. Seiwell (1937, p. 19) has pointed out that "from general oceanographic knowledge it seems probable that the biological activity of the water mass plays an important role in fixing the minimum oxygen concentration at mid depths. This may be brought about either by a maximum concentration of oxidizable organic matter at the depth of the oxygen minimum concentration, or (if the supply of oxygen by horizontal currents varies with depth) by vertical variations of biological activity causing the ratio O_2 utilized/O_2 supplied to be continuously increased as the depth of the minimum oxygen concentration is approached both from above and below." The concentration of the Copepod fauna, in both the number of species and individuals present, at or near the depth of the minimum oxygen concentration is in keeping with the



Text-fig. 75.—A Section of the Atlantic Ocean showing the depth of the O_2 minimum layers (after Defant, 1936, and Wüst, 1936) and the position of the maximum concentration of species in different regions.

view expressed by Seiwell that biological activity plays an important part in causing this minimum.

One of the most important factors in the distribution of species is the temperature of the water in which they are living, and especially of the range of temperature from season to season or from one point in a current system to another. Rose (1925, p. 518) has put forward the view that, if there be any marked difference in either temperature or salinity between the current and its surrounding water, such a current will serve as a barrier to the horizontal propagation of species, as suggested by Chun, but will also tend to retain its own peculiar fauna until, as one follows the current along, the difference between it and the surrounding water gradually lessens, and a stage is eventually reached where the indigenous fauna of the current can pass out of its limits into the surrounding ocean, or, *vice versa*, species characteristic of the surrounding ocean can pass into the current until finally the individual peculiarities of the fauna within and outside the stream disappear and the fauna becomes homogeneous. Störmer (1933) has pointed out that in a single current system, such as the Gulf Stream and its continuation the North Atlantic Drift, the pelagic life is in its origin tropical, but that very few of the different species manage to enter the North Sea and succeed in breeding there; the water of a current



TEXT-FIG. 76.—A Section of the Indian Ocean showing the O_2 concentration at different depths (after Clowes and Deacon, 1935) and the position of the maximum concentration of species in different regions in the Indian and West Pacific areas.

such as this appears to be characterized by a steadily increasing deficiency of certain species, and furthermore, the extreme limit to which any given species can be carried and still survive will vary from season to season and from year to year with changes in the hydrographical conditions, and especially in the temperature, the more resistant species being carried farther northward than the less resistant forms. In this great current system there is at its origin an average annual temperature of about 27° C., with a range of about 5·5° C., whereas as we follow its course across the Atlantic Ocean and on past the north coast of Norway the temperature falls to 0° C., or even less, in the Arctic region. For each species there is a definite temperature range within which the species can continue to live, but there is a much smaller range within which it can reproduce, and a still smaller one within which the species can be at its optimum. As each species passes out of the temperature range within which it can reproduce, its final disappearance becomes a certainty, the actual place depending on the length of life of the individual and the rate of the current. Pfeffer (1903) states that " it is easy to understand that, owing to the depressant effect of low temperatures upon metabolism, they should take longer to produce a fatal effect than high ones, which steadily accelerate respiration." He was referring to the effects of temperature on plant life, but the same must equally apply to animals; and Edmondson (1928, p. 26) remarks " that living organisms are more capable of enduring a gradual reduction of temperature than a gradual increase of temperature is well known." Many species, and even genera, tend to be limited to a particular current system, or set of systems, as has been clearly demonstrated in the case of the genus *Copilia* by Lehnhofer (1926); and the number of species that can survive a transfer from one system to another will depend on the hardiness of the individual and the extent of the change in physical conditions, especially that of temperature, which such a transfer entails, and the suddenness with which this change is brought about. The boundaries between such current systems in the surface waters, where these changes are most marked, are the Sub-tropical and Sub-polar convergence zones, and it is especially along these lines that we find the main barriers to the passage of epi-planktonic species either from warm to cool or cold water in the case of species that have originated in the tropical and temperate regions or from cold or cool water to warm for species that have evolved in northern or southern latitudes. That the passage from cold to warm water is much more effective as a barrier to the transfer of Copepoda than a change in the opposite direction is clearly indicated.

Wolfenden (1908 and 1911) has shown that in the Indian Ocean immediately to the north of New Amsterdam Island there is a radical change in the character of the Calanoid fauna and that, similarly, in the Atlantic Ocean true Antarctic species are to be found only as far north as lat. 40° S., but that a few typical Atlantic deep-water species can penetrate into the Antarctic; I have shown (Sewell, 1940*a*, p. 361) that the same holds good for the weed-haunting Harpacticids. Among the planktonic Copepoda some 43 species of warm-water, epi-planktonic Calanoids from the Indo-Pacific region have been able to extend their range southwards into the cool water of the West Wind Drift, and 20 have actually got as far as the cold Antarctic region (*vide infra*, p. 453), whereas not a single species that has been evolved in the southern cold region has been able, so far as I know, to pass northwards across the convergence zones and so become an ingredient of the epi-planktonic fauna of the warm-water regions, though they may be carried northwards in the deeper cold currents. This division into warm-water and cold-water faunas is not a hard and fast one, and the boundary between the various faunas may vary from season to season and year to year. Mackintosh (1934) in his review of the distribution of the Antarctic Macro-plankton has shown that "the evidence leaves no reasonable doubt (1) that in the South Georgia plankton the cold-water species are most strongly represented in the spring, and that as the summer advances they are reduced and the warm-water species gain ground, and that the warm-water plankton continues right through the winter; (2) that an abnormally cold summer results in a 'colder' plankton which, however, still becomes 'warmer' as the summer passes." It is generally recognized that one of the chief factors in regulating the distribution of the Copepoda is the temperature of the water. A great deal of work will be necessary before we can hope to have an adequate knowledge of the temperature range of all the various species, but already it is evident that this range differs widely in different species, even in those of the same genus. Ruud (1929) gives the range for *Calanus finmarchicus* (Gunn.) as extending from 2·0° C. to 22·0° C., whereas in *Calanus hyperboreus* Kröyer it is only from 5·0° C. to 7·5° C. Steuer (1931*a*) in the genus *Rhincalanus* gives for *R. cornutus* (Dana) a range from 3·5° C. to 27·5° C. for the f. *typica** and from 4·5° C. to 17·5° C. for the f. *atlantica*; for *R. nasutus* Giesbr. he gives a range of – 0·5° C. to 15·5° C., and for the same species Schmaus and Lehnhofer (1927) give ranges of from 3·0° C. to 20·0° C. in the Indian Ocean and from 3·0° C. to 15·0° C. in the Atlantic. For *R. gigas* Brady, Steuer (*loc. cit.*) gives a range from – 2·0° C. to 7·5° C. Among other species that appear to possess a moderate or wide temperature range the following may be mentioned:

Species.	Temperature range. (° C.)
Paracalanus parvus (Claus)	– 1·23 to 28·0
Scolecithricella minor Brady	– 1·23 ,, 28·0 ?
Pseudocalanus elongatus (Boeck)	– 1·23 ,, 13·0
Temora longicornis (O. F. Müll.)	5·0 ,, 25·0 ?
Scolecithricella ovata Farran	2·9 ,, 10·0
Euchirella rostrata (Claus)	2·9 ,, 13·5
Metridia lucens Boeck	4·83 ,, 16·1

The upper limit in the case of the 2nd and 4th species in the above list is open to some doubt, and depends, as all such records must do, on the correct identification of the species.

Ability to exist and to breed in a wide temperature range will enable a species to survive transportation by currents for long distances, and thus to extend its habitat horizontally in the surface layer from the tropics to temperate or even cool regions, and in extreme cases to Arctic or Antarctic latitudes, and vertically from the surface down to considerable depths. Ekman (1935, p. 93) emphasizes that the temperature of the water is one of the most important factors in determining the distribution of the marine fauna; he follows Ortmann (1896) in taking the annual mean isotherm of 20° C. in the surface water as forming the boundary between the tropical and the northern and southern faunas, and he claims that this is in agreement with the conditions found in various regions, such as South Africa, Japan, Australia, and North and South America. As regards the first of these localities Stephenson (1944) remarks, "It would therefore appear that the most rapid disappearance of animal species takes place as soon as the mean annual temperature falls distinctly below 20° C.," and he adds, " this agrees rather well with Vaughan's statement that 'it seems that a continuous bottom temperature of about 21° C. is the lowest at which reef-forming corals may be expected to live'." Fritsch (1945), in an article on *Ceratium* and Marine Hydrography, defines the tropical species as those which are intolerant of cold water and are fairly closely confined to water having a temperature of 19° C. and over; but he points out that the Gulf Stream carries *Ceratium extensum* to the British Isles, where the temperature is 12·4° C., and *C. hexacanthum* to Iceland, where the surface temperature is as low as 8·9° C., though in other areas these two species are not found below 14·9° C. and 18·9° C. respectively. While a temperature of 20° C. may be

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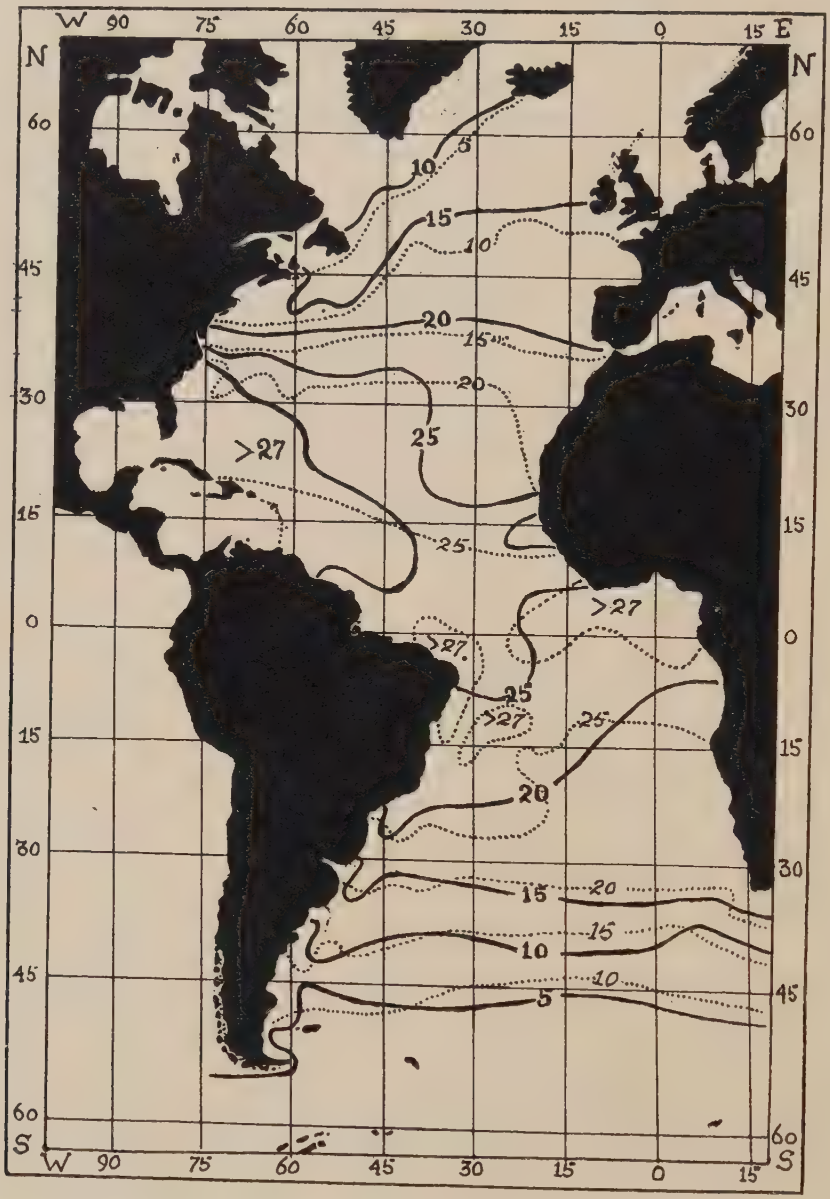
* In a later work, Steuer (1937, p. 138) records the presence of a female and a young male in the South Atlantic at a depth of 700 m. and in a temperature of 2·6° C.



TEXT-FIG. 77.—Showing the isotherms of the surface-water in the Atlantic Ocean in the months of February and August. (From Harvey, 1945.)

critical for littoral-haunting animals, it seems to me that it is rather too high for the epi-planktonic Copepod fauna, and that the limiting temperature falls nearer to 15° C. So far as the genus *Sapphirina* is concerned nearly every recorded catch falls within the limits of this annual mean isotherm (*vide* Text-fig. 83), the only exceptions being a few scattered records in the Antarctic and along the north Atlantic Drift. During the course of the year the position of the 15° C. isotherm in the North Atlantic changes its position (Text-fig. 77): in the month of August the maximum temperature of the surface water in the tropical region lies off the west African coast, in about lat. 15° N., and the 15° C. isotherm strikes the British Isles in about 53° N., whereas in February the highest temperatures are found on the African coast in the Gulf of Guinea at about the level of the equator, and the 15° C. isotherm strikes the entrance to the Strait of Gibraltar. A study of the distribution of the warm-water epi-planktonic species shows that a number of these, which are normal inhabitants of the warm surface waters of the Indo-Pacific and Atlantic tropical regions in temperatures of over 25° C., are still found in the North Atlantic as far north as lat. 40°–50° N. On the American side in the region of Woods Hole and Cape Cod, in lat. 40°–42° N., these Indo-Pacific species form 68 per cent. of the total number of epi-planktonic species that have been recorded, while on the European side off the south-west corner of Ireland, in lat. 52°–54° N., they still form 53 per cent. A reference to Text-fig. 77 shows that these regions correspond closely with the isotherm of 15° C. of the surface water during the month of August. Similarly, in the southern Hemisphere Wolfenden, as already mentioned, has suggested that the line of lat. 40° S. marks the boundary between the warm-water and the true Antarctic species, and a reference to Text-fig. 77 shows that this corresponds in the South Atlantic Ocean reasonably closely with the isotherm of 15° C. in the month of February.

Farran (1926) has given tables showing the depth distribution of certain species that were taken in the Bay of Biscay, and in these one notes the presence in very considerable depths of species that are normally to be found in the surface layer :

Species.		Depth in metres.	
Ægisthus mucronatus Giesbr.	down to	1372	(750 fms.).
Eucalanus crassus Giesbr.	,,	1372	,,
Scolecithricella dentata Giesbr.	,,	1372	,,
Paracalanus parvus (Claus)	,,	1830	(1000 fms.).
Euchaeta acuta Giesbr.	,,	1830	,,
Centropages typicus Kröyer	,,	1830	,,
Oithona atlantica Farran	,,	1830	,,
Oithona similis Claus	,,	1830	,,
Ctenocalanus vanus Giesbr.	,,	2286	(1250 fms.).
Clausocalanus pergens Farran	,,	2743	(1500 fms.).
Acartia clausi Giesbr.	,,	2743	,,
Pseudocalanus elongatus (Boeck)	,,	3000	(1700 fms.).
Clausocalanus arcuicornis (Dana)	,,	3658	(2000 fms.).

Wolfenden (1904) has recorded the presence of *Anomalocera patersoni* Templ. at a depth of 750 m. in the North Atlantic and *Ectinosoma atlanticum* Brady (=*Microsetella norvegica* (Boeck)) at 2195 m. Ruud (1929) has given data from several authors for *Calanus finmarchicus* (Gunn.), and he shows that whereas the low limit of distribution is usually about

200 m., examples have been taken by Paulsen off Iceland down to 500 m. and by Damas and Koefoed in the northern Norwegian Sea as far down as 1200 m.; Murray and Hjort (1912) have recorded it as deep as 1600–1850 m. Leavitt (1938) has recorded *Euchæta marina* (Presland.) and *Rhincalanus cornutus* (Dana) at a depth of 2400 m., and Wilson (1932, p. 23) records *Nannocalanus minor* (Claus) from a depth of 2743 m. in the Woods Hole region. Another surface-living species that has been recorded from considerable depths is *Microcalanus pygmæus* Sars, down to 1200 m. Wolfenden (1911) has recorded no less than 37 species, that are normally to be found in the surface layer from 0 to 400 m., which were taken by the "Gauss" at a depth of 3000 m. These are:

Eucalanus monachus Giesbr.
E. mucronatus Giesbr.
Rhincalanus cornutus (Dana).
Scolecithrix danæ (Lubb.).
Scolecithricella bradyi (Giesbr.).
Centropages violaceus (Claus).
Candacia bispinosa Claus.
C. longimana Claus.
C. pachydactyla Dana.
C. varicans Giesbr.
Labidocera acutifrons (Dana).
Oithona linearis Giesbr.
O. plumifera Baird.
O. similis Claus.
Oncæa conifera Giesbr.
O. mediterranea Giesbr.
O. venusta Philippi.
Lubbockia aculeata Giesbr.
L. squillimana Claus.
Corycæus alatus Giesbr.
C. furcifer Claus.
C. longistylis Dana.
C. ovalis Claus.
C. speciosus Dana.
Corycella gibbula (Giesbr.) (= *pelucidus* Dana).
Saphirina angusta Dana.
S. intestinata Giesbr.
S. metallina Dana.
S. opalina Dana.
S. ovato-lanceolata Dana.
Copilia denticulata Claus.
C. lata Giesbr.
C. mirabilis Dana.
C. quadrata Dana.
C. vitrea Giesbr.
Macrosetella gracilis (Dana).
Ægisthus mucronatus Giesbr.

The positions at which these catches were made all lie between lat. 35° S. and 35° N., and reference to the salinity charts of the Atlantic Ocean given by Wüst (1928, Pl. XXXIII) shows that they correspond to the North Atlantic Intermediate water, that is sinking down in the North Atlantic between lats. 20° and 50° N. There can be little doubt that as this water-mass sinks down and then flows southwards it carries with it numerous species that normally are to be found inhabiting the warm, tropical and subtropical surface layer.

On the other hand certain species that are normally to be found inhabiting the cold deep strata are occasionally taken in the surface layer. We have already seen that these species are probably associated with the "Stratosphere" layer of the ocean, and one would thus expect to find a number of these at or near the surface in the polar regions where the "Troposphere" stops short at the Polar Front and the "Stratosphere" comes to the surface, but their presence in the surface layer in the tropical and subtropical regions must have entailed their passage through or at least into the Troposphere, so as to permit of their presence between 0 and 400 m. depth, or in some instances from 0 to 100 m., while individual specimens are by no means uncommon actually on the surface. I have been able to collate such records of the following species :

Calanus finmarchicus (Gunn.).
C. helgolandicus Claus.
C. hyperboreus Kröyer.
C. tenuicornis Dana.
Calanoides brevicornis (Lubb.).
C. patagoniensis (Brady).
Megacalanus princeps Wolfend.
Bathycalanus princeps (Brady) (=*rigidus* Sars).
Neocalanus gracilis (Dana).
N. robustior (Giesbrecht).
Eucalanus attenuatus (Dana).
E. elongatus (Dana).
Rhincalanus nasutus Giesbr.
Spinocalanus abyssalis Giesbr.
S. caudatus Sars.
S. magnus Wolfend.
S. spinosus Farran.
Euætideus giesbrechti (Cleve).
Ætideus armatus Brady.
A. bradyi A. Scott.
Pseudætideus armatus (Boeck).
Chiridius gracilis Farran.
C. poppei Geisbrecht.
Chirundina indica Sewell.
C. streetsi Giesbr (juv.).
Undinopsis bradyi Sars.
Gætanus armiger Giesbr.
G. kruppi Giesbr.

G. latifrons Sars.
G. miles Giesbr.
G. minor Farran.
G. pileatus Farran.
Gaidius tenuispinus (Sars).
G. affinis Sars.
G. pungens Esterly.
Euchirella amœna Giesbr.
E. bella Giesbr.
E. brevis Sars.
E. curticauda Giesbr.
E. galeata Giesbr.
E. intermedia With (=*truncata* Esterly).
E. messinensis (Claus).
E. orientalis Sewell.
E. pulchra (Lubb.).
E. rostrata (Claus).
Undeuchæta bispinosa Esterly.
U. major Giesbr.
U. plumosa (Lubb.).
Pseudochirella magna (Wolfend.) (juv.).
P. divaricata. (Sars).
Valdiviella minor Wolfend.
Euchæta hebes Giesbr.
E. spinosa Giesbr.
E. tenuis Esterly.
Paraeuchæta grandiremis (Giesbr.).
P. incisa Sars.
P. investigatoris Sewell.
P. flava (Giesbr.).
P. norvegica Boeck.
P. tonsa (Giesbr.).
P. tumidula Sars.
P. weberi A. Scott.
Phaenna spinifera Claus.
Amallophora typica T. Scott.
Heteramalla dubia (T. Scott).
Onchocalanus cristatus (Wolfend.).
O. nudipes Wilson.
O. trigoniceps Sars.
Scottocalanus dauglishi Sewell.
S. helenæ (Lubb.).
S. securifrons (T. Scott),
Lophothrix latipes (T. Scott).
L. frontalis Giesbr.
L. humilifrons Sars.

Scaphocalanus brevicornis (Sars).
S. curtus (Farran).
S. echinatus (Farran).
S. elongatus A. Scott.
S. medius Sars.
S. magnus (T. Scott).
Scolecithricella abyssalis (Giesbr.).
S. auropecten (Giesbr.).
S. dentata (Giesbr.).
S. marginata (Giesbr.).
S. porrecta (Giesbr.).
S. vittata (Giesbr.).
Amallothrix arcuata Sars.
A. obtusifrons Sars.
A. propinquus Sars.
A. valida Farran.
Temoropia mayumbæensis T. Scott.
Metridia brevicauda Giesbr.
M. curticauda Giesbr.
M. longa Lubb.
M. lucens Boeck.
M. princeps Giesbr.
Pleuromamma abdominalis (Lubb.).
P. gracilis (Claus).
P. indica Wolfend.
P. quadrungulata (Dana).
P. robusta (Dahl).
P. xiphias Giesbr.
Lucicutia bicornuta Wolfend. (= *aurita* Sars).
L. clausi Giesbr.
L. flavicornis (Claus).
L. grandis Wolfend.
L. longicornis Giesbr.
L. ovalis Wolfend.
Heterorhabdus abyssalis (Giesbr.).
H. compactus Sars.
H. norvegicus (Boeck).
H. papilliger (Claus).
H. spinifrons Claus.
Heterostylites longicornis (Giesbr.). or Claus? Sa [illegible]
Disseta palumboi Giesbr.
Augaptilus longicaudatus (Claus).
Euaugaptilus filigerus (Claus).
E. hecticus Giesbr.
E. longimanus Sars.
E. nodifrons Sars.

Haloptilus acutifrons (Giesbr.).
H. angusticeps Sars.
H. bulliceps Farran.
H. longicornis (Claus).
H. ornatus (Giesbr.).
H. oxycephalus Giesbr.
H. plumosus (Claus).
H. spiniceps (Giesbr.).
Centraugaptilus rattrayi (T. Scott).
Arietellus aculeatus (T. Scott).
A. giesbrechti Sars.
A. setosus Giesbr.
Phyllopus helgæ Farran.
Candacia norvegica Boeck.
Mormonilla phasma Giesbr.

In certain areas, especially in the temperate zone, species that in the tropical region belong undoubtedly to the deep-water group may form an apparently normal ingredient of the surface-water fauna. Such a region is to be found off the west coast of North America in the San Diego region of the Californian coast, where such species as *Eucalanus elongatus* (Dana), *Gaidius pungens* Giesbr., *Undeuchæta bispinosa* Esterly, *Metridia lucens* Boeck and *Pleuromamma abdominalis* (Lubb.) have been taken frequently in the surface tow-net (*vide* Esterly, 1912). The majority of examples taken on the surface were obtained at night, and this is to some, and possibly a very considerable, extent to be attributed to daily vertical migration ; but it is possible that the presence of these species at a level sufficiently high to enable their daily vertical migration to bring them to the surface may to some extent be correlated with the upwelling of deep water which is known to occur along this coast, especially during the spring months.

Damas (1905), in his study of the Copepoda of the Norwegian Sea, found that certain species tended to occur at a given level. He remarks (*loc. cit.*, p. 22) : " *Metridia* apparait souvent dès 100 m. de profondeur, *Euchæta glacialis* parait aussi vivre dans une zone intermédiaire, tandis qu'*Euchæta barbata* appartient à la faune profonde." Wilson (1942, p. 8), in his account of the work of the " Carnegie " in the Pacific Ocean, also states that " the different species of copepods that are found near the surface of the ocean in the day-time show a marked tendency to arrange themselves in zones or layers parallel with the surface. Some species are practically confined to the surface tows, of which they constitute a very large percentage. . . . Others are confined entirely or very largely to the 50-metre tow, and still others apparently do not approach nearer to the surface than the 100-m. tow." The evidence that he gives is by no means conclusive. It is well known that many of the surface-living species are to be found at a lower level during the daytime and the depth to which they descend appears to be in the main correlated with the intensity of the light that is present, so that this varies from day to day (*vide infra*, p. 354). As regards the species that do not usually appear higher than the 100 m. tow-nettings, a study of Wilson's lists reveals that these are for the most part, if not entirely, species that normally inhabit much greater depths, and belong to the deep-dwelling group of species that has its maximum intensity at about 1000 m. depth. It is interesting to note that out of the 135 species listed above as many as 75 are known to be present in all three great oceans, Atlantic, Indian and Pacific, and 34 or 35 have been recorded from the Antarctic. Clearly these are widely dispersed species, and hence would be most liable to become involved in any unusual disturbance in the ocean that might set up convection currents and vortices and so bring the deep fauna to the surface.

Such an upward transference of individuals, belonging to species that normally inhabit deep and cold-water strata, into the warm upper-surface layer will expose them to a relatively rapid rise in the temperature of their surroundings, and, as we have already seen, such a change is likely to prove fatal; it will also expose them to a very considerable reduction of pressure. It seems doubtful whether such examples could survive this change, and in consequence whether such a vertical transference into a superficial current of the "Troposphere" could affect the horizontal distribution of the species as a whole. In certain instances, however, such an upwelling may perhaps not be immediately fatal, especially to immature stages, and so might permit of the transference over comparatively short distances, as from the Atlantic Ocean to the Mediterranean Sea (*vide infra*, p. 511). In the Atlantic Ocean a vertical upward movement from the depth of about 1500 m. to about 300 m. will be correlated with a change of temperature from about 3° C. to about 12° C., which is probably within the limits of tolerance of many of the species given above, and as at first the upwelling water will tend to retain the temperature of the zone from which it started and will only subsequently become warmed up to that of the upper level, any adverse effect on the individual will be delayed.

In a few areas the main factor limiting the horizontal distribution of a species appears to be, not temperature, but the salinity of the water, and Wilson (1942, p. 7) has pointed out that "a high salinity is known to be adverse to ordinary pelagic copepods, and it is possible that when combined with a fairly high temperature it may become a deterrent to copepod life in the epiplankton." Farran (1920, p. 15) remarks regarding the species *Calanus finmarchicus* (Gunn.), "This species is sometimes referred to as being oceanic because it is intolerant of inshore conditions, probably on account of low salinity, but high salinity seems to furnish an equally efficient bar to its seaward extension"; this seaward limit coincides approximately with the isohaline 35·35 ‰.

Another factor that must be considered is the ability of individual specimens to withstand changes of pressure, and especially of a reduction of pressure, such as must be experienced when being carried upwards in convection or other currents, and of many, if not most, species to become adapted to very greatly increased pressure, and hence to possess an equally great vertical range of habitat. As regards the effect on the individual Cattell (1936) has reviewed our knowledge of the subject, and he remarks: "The fact that deep-sea forms have as their normal habitat pressures great enough to produce important physiological changes and even death in organisms living near the surface is a significant observation which seems to have attracted very little attention since Regnard's pioneer studies." Regnard (1884 and 1891) carried out a number of experiments on various organisms, subjecting them to pressure of 400 to 1000 atmospheres. Cattell (*loc. cit.*, p. 454) sums up these experiments as follows: "Thus examples of surface fauna are killed when exposed to pressures comparable to those tolerated by deep-sea species, and conversely the deep-sea forms die when brought to the surface." As he points out, "the study is a difficult one, for in bringing a deep-sea animal to the surface not only is the pressure changed but many other environmental factors, such as light, temperature, and the concentration of dissolved gases." Heilbrunn (1937, p. 348) states that "Cœlenterates exposed to 1000 atmospheres were inert and their weight about twice what it was originally. Similar effects were obtained with tunicates and worms. Crustacea, protected by their carapace, withstand high pressures better." That species are able to adapt themselves to a wide range of pressure is beyond doubt. The work of Farran (1926), Jespersen (1934) and others has shown that numerous species possess a wide vertical range, and hence are able to exist in a very considerable range of pressure. It is this ability to withstand a great range of pressure that enables species to be involved in the phenomenon of submergence. Ekman (1935, p. 323 *et seq.*) has pointed out that there are two types of such submergence, namely towards the poles and towards the equator, and it is the latter type that is most frequent. He further points out that both kinds of submergence are simple consequences of the temperature distribution, and that the submergence of the animal distribution runs parallel with the submergence of the water temperature and the water itself; in other words, the animals are carried downwards to deeper levels in the sinking polar or boreal water-masses, and at the same time are transported horizontally from one region to another. Giesbrecht (1892) stated most emphatically that deep-sea species of warm seas were *not* met with in the Arctic regions; but it is now well known that certain species, as an example of which we may take *Pseudocalanus elongatus* (Boeck) (= *minutus* Kröyer), are common at or near the surface in the Arctic and Antarctic regions, but that in lower latitudes, near or at the equator, they are found to be living at considerable depths. Conversely Jespersen (1934) has shown that in West Greenland waters the warm-water, surface species *Paracalanus parvus* (Claus) was usually taken at considerable depths, with 1000 to 2500 m. of wire out, which he estimated (*loc. cit.*, p. 7) corresponded to an actual vertical depth of one-half or two-thirds of this figure, namely from 500 to 1667 m. Leavitt (1938), in his studies of the vertical distribution of the macroplankton in the western Atlantic basin, obtained evidence of two maxima, the one at about 800 m. depth and the second at about twice this depth, and he suggested that this deeper maximum can be accounted for on the supposition that "sinking water masses from more moderate depths in somewhat higher latitudes may bring their planktonic communities with them and so be responsible for richer strata below poorer further south. This (last) seems the most probable explanation for such a distribution in the present case, because species of decapods, copepods, cœlenterates and euphausiids occurring at moderate depths somewhat farther north have been prominent in the catches where total volumes have revealed the existence of secondary maxima deep down." Such a passive transference of species from the surface stratum in high latitudes both north and south of the equator is continually going on and is now recognized to be a well-established phenomenon. Russell (1935) has pointed out that "the ocean circulation is in favour of carrying any northern species that can withstand and reproduce under deep-water conditions southwards to the Antarctic." It is not every species that can resist the changes experienced in such a transfer, but a number of Arctic forms have been swept as far as the tropical region, where they are found in deep water, and still more have been carried from the north temperate region to the Sub-Antarctic area. Such a transfer does not, however, entail a very great change of temperature, and a gradual sinking from the surface in northern latitudes to a depth of 2000 m. in the tropics may be accompanied by a change of only some 2° C. in temperature; and moreover such a change must be extremely gradual since the actual rate of flow of the deep currents is slow, though it may perhaps vary considerably from region to region and from depth to depth. Various attempts have been made to estimate the speed of these deep currents: in the Antarctic, in the region to the east of South Georgia, the water of the upper stratum is moving northwards, but the rate of this movement varies very considerably at different depths, and Hardy and Gunther (1935, p. 348), quoting results obtained by Deacon, give the figure of 5·5 miles per day at the surface and of only 2·3 miles per day at a depth of 400 m. Wattenburg (1927) suggested a speed of some 3–4 cm. per sec. (or 511–683 miles per annum) in the Intermediate and Deep currents of the North Atlantic. Soule (1938), from a variety of different kinds of evidence, suggests that off the Grand Banks at 3500 m. depth the water is moving south at a speed of 6·6 cm. per sec. (or 1141 miles per annum), but that at a point to the south-east of the tail of the Grand Bank the speed is reduced to 2·6 cm. per sec. (or 438 miles per annum). Wüst (1935) quotes an estimate, reached by Castens from a study of the observations taken by the "Deutschland" and the "Dana," of 3·5 cm. per sec. (or 595 miles per annum), and he suggests that, if the observations on which all these calculations are made truly reflect actual changes due to movement of the various water masses, the upper deep stratum, the Sub-Antarctic intermediate water, moves northwards at a rate of 3·8 cm. per sec. (or 647 miles per annum) in the main axis of the stream, and that the middle deep water, the North Atlantic Intermediate water, moves southwards in the main axis of the current at a speed ranging from 3·5 to 3·8 cm. per sec. (or 595–647 miles per annum). Seiwell (1934 and 1938), from a study of the oxygen-content of the water of the North Atlantic, concludes that the rate of flow of the North Atlantic Intermediate water is only about 1·4 cm. per sec. (or 272 miles per annum), and Deacon (1933), basing his calculations on the differences of oxygen-content and salinity variations, postulates a speed of about 1·3 miles per day (or 474·5 miles per annum) in lat. 40° S. and 2·5 miles per day (or 912·5 miles per annum) in lat. 7° S. in the South Atlantic Intermediate water, the difference between these two estimates being due to the decreasing thickness of the layer and the narrowing of the Atlantic basin. It would thus take a mass of water and its contained plankton some 9 years or more to get from lat. 60° N. or S. to the Equator, which agrees moderately well with the suggested 7 years, as indicated by Deacon, to get from about lat. 40° S. to the Equator. During such an interval of time there will have been a succession of generations in the drifting Copepoda. In *Calanus finmarchicus* (Gunn.) there are known to be two or three generations in a year in the cold northern surface waters, and since there is little or no change in temperature in the water that is sinking down to form the Intermediate current, it seems probable that a similar rate of reproduction persists in the cold deep water of the equatorial region. The change of pressure that is entailed in such a transfer from the surface to a depth of some 2000 m. amounts to approximately an increase from one atmosphere, or 15 lb. to the square inch, at the surface to about 200 atmospheres, or 206·6 kg. per sq. cm., at 2000 m.; but this increase, great though it be, will be spread over some 18 or more generations, even if the drift be a continuous one in a straight North-South direction.

Rose (1925) has published a detailed survey of the various factors that can influence the daily vertical migration, and Russell (1927) has admirably summarized our knowledge, up to the date of publication of his paper, of the vertical distribution of the plankton, and he has grouped the various changes under the following headings:

1. Regional changes in vertical distribution.
2. Seasonal changes.
3. Daily changes.

4. Ontogenetic changes.
5. Changes due to spawning habits.
6. Special variations due to hydrographic conditions.

Most of the work on the subject of vertical migration has been carried out on organisms that inhabit the surface water of the Atlantic Ocean, and among the Copepoda it has been shown that *Calanus finmarchicus* (Gunn.) and *Candacia armata* Boeck (*vide* Russell, 1928, Gardiner, 1931, and Clarke, 1934*a*), *Centropages typicus* Kröyer (*vide* Clarke, 1933), *Metridia lucens* Boeck (*vide* Clarke, 1933), *Calanopia americana* F. Dahl (*vide* Clarke, 1934*b*), and *Acartia spinata* Esterly (*vide* Clarke, 1934*b*) appear to carry out diurnal migrations, swimming up towards the surface at night and sinking down to deeper levels in the day. Esterly (1912), working on the fauna of the Pacific Ocean, has shown similar daily vertical migrations in *Calanus finmarchicus* (Gunn.), *Metridia lucens* Boeck, *Labidocera trispinosa* Esterly, *Euchirella pulchra* (Lubb.), *E. rostrata* (Claus), *Gaidius pungens* Giesbr., *Pleuromamma abdominalis* (Lubb.), *P. gracilis* (Claus), *Rhincalanus nasutus* Giesbr. and *Undeuchæta bispinosa* Esterly. Hardy and Gunther (1935), working in the Antarctic region, have recorded evidence of similar migrations of a diurnal character in *Calanus similimus* Giesbr., *Clausocalanus laticeps* Farran, *Ctenocalanus vanus* Giesbr., *Drepanopus pectinatus* Brady, *Paraeuchæta antarctica* Giesbr., *Pleuromamma robusta* (F. Dahl) *Metridia gerlachei* Giesbr. and *M. lucens* Boeck; and Mackintosh (1934) has shown that similar migrations can be detected in species (unidentified) of the genera *Paraeuchæta*, *Euchirella* and *Heterorhabdus*. Russell (1928, 1932), from his studies in the Plymouth area, showed that at one season of the year a daily vertical migration of *Calanus finmarchicus* (Gunn.) appears to be a regular phenomenon, individuals coming up to the surface at night and migrating downwards in the daytime. Gardiner (1933), working in the North Sea, found, however, that the migration was of an exactly opposite nature, so far as adults and Stage V individuals were concerned, for the greater number were taken at or near the surface at mid-day and sank down to 28 fms. (51 m.) at midnight.

It is now generally accepted that one of the main factors that induce this daily vertical migration is the direction and intensity of the light at different depths, but other factors may be concerned, and Ostwald (1902) has put forward the view that the physico-chemical characteristics of the water and of the planktonic individual have a profound effect. The two most important factors in his mechanical theory of migration are the size and shape of the planktonic organism, which influences the amount of friction between the animal or plant and the surrounding water, and its specific gravity on the one hand, and the viscosity of the water, which is varied by changes of temperature and salinity or the degree of concentration of suspended material, on the other. Ostwald thus explains the daily vertical migration of the plankton as follows: at sunrise the plankton is found in greatest abundance on the surface; as the day advances the surface-water becomes heated up and this reduces the density of the water and decreases the friction and viscosity, so that planktonic organisms will begin to sink and will continue to do so till they reach a level at which the density of the water and its viscosity is sufficient to counteract the tendency of the organism to sink, and at that level the plankton will float freely. By night the plankton has become accumulated at a certain depth below the surface, but as the surface water cools it becomes more dense, and at the same time the deeper water becomes warmer and thus vertical currents are set up (the daily "change-over"), and the plankton is then carried mechanically to the surface again by the ascending currents and will be found there in the early hours of the next day. Differences in different organisms will affect the extent and rapidity of these passive movements: larger organisms will sink more rapidly and to a greater depth than smaller ones, hence the adult Copepoda will reach a deeper level than the immature and larval stages; and powerful swimmers will have a greater amplitude of range than those less powerful.

One factor, therefore, that must tend to produce a stratification in the distribution of individuals of different sizes and developmental stages is the rate at which they will sink, if active swimming be suspended or be insufficient to counteract the rate of sinking. Gardiner (1933), from a study of anæsthetized individuals of *Calanus finmarchicus* (Gunn.), found that in the North Sea examples that were taken near the surface had an average length of 2·76 mm., those at mid-water 2·82 mm., and finally those from near the bottom averaged 2·94 mm. From the data that he gives (Table VIII) we are able to calculate the rate of sinking of the different developmental stages, as follows:

Stage.	Number of examples.	Range of size (length). (mm.)	Time taken to sink through 250 mm. of water. (Average.)
IV	21	2·1 to 2·4	124·1 seconds
V	41	2·6 ,, 3·2	99·35 ,,
VI ♀	53	2·8 ,, 4·0	59·3 ,,
♂	5	3·0 ,, 3·5	49·3 ,,

Gardiner also states that in the North Sea during the course of his investigations Stages IV and III did not sink down like the older specimens, and Nicholls (1933), in the Clyde Sea-area, noted that "the stimulus to withdraw from bright light does not affect the nauplii, but becomes increasingly effective as development proceeds, so that there is a tendency for the 3rd Copepodites to migrate downwards during the day. . . . In adults, particularly the females, heliotropism in *Calanus* is developed to its fullest extent."

A number of the surface-living Copepoda are known to exhibit a seasonal migration, occurring at or near the surface at one period of the year and inhabiting a lower stratum at another. Here again a number of factors appear to be involved. Russell found that in the Plymouth area adults of *Calanus finmarchicus* (Gunn.) were found at a depth of 10 m. in the month of April but were at 20 m. in June, and were found again to be nearer the surface in July, August and September. To explain this difference he suggests that successive broods may be physiologically different, some preferring a higher light intensity than others, though he qualifies this conclusion, pointing out that so little is yet known of the actual seasonal changes in light conditions beneath the surface that we cannot say that an apparent seasonal change in the behaviour and reactions of *Calanus* is not entirely due to changes in external conditions and not to any physiological difference at all. Several other Authors have recorded *Calanus finmarchicus* (Gunn.) to be swarming at the surface during the day in various regions in the following months:

Sömme (1933) in the month of April.
Marshall and Orr (1927) occasionally in April, and in May and June.
Brook (1886) in May and June.
Herdman (1919) in July.
Bigelow (1926) in July.
Russell (1928) in July and August.
Willey (1919) in September.

Mackintosh (1937) has shown that in Antarctic waters such a seasonal vertical migration may be extremely marked: thus *Rhincalanus gigas* Brady is to be found in large numbers in the upper layer between 0 and 200 m. in December, whereas in September there are very few in the surface layer and the great majority occur at about 500 m. *Calanus acutus* Giesbr. in September has completely deserted the surface layer and has sunk to depths as great as 750–1000 m. or even more, but in December it appears on the surface. Mackintosh relates this vertical migration to the movements of the antarctic water layers, and he remarks, " It is to be supposed that this vertical migration results in a large-scale circulation by means of which these species keep within the limits of their normal distribution."

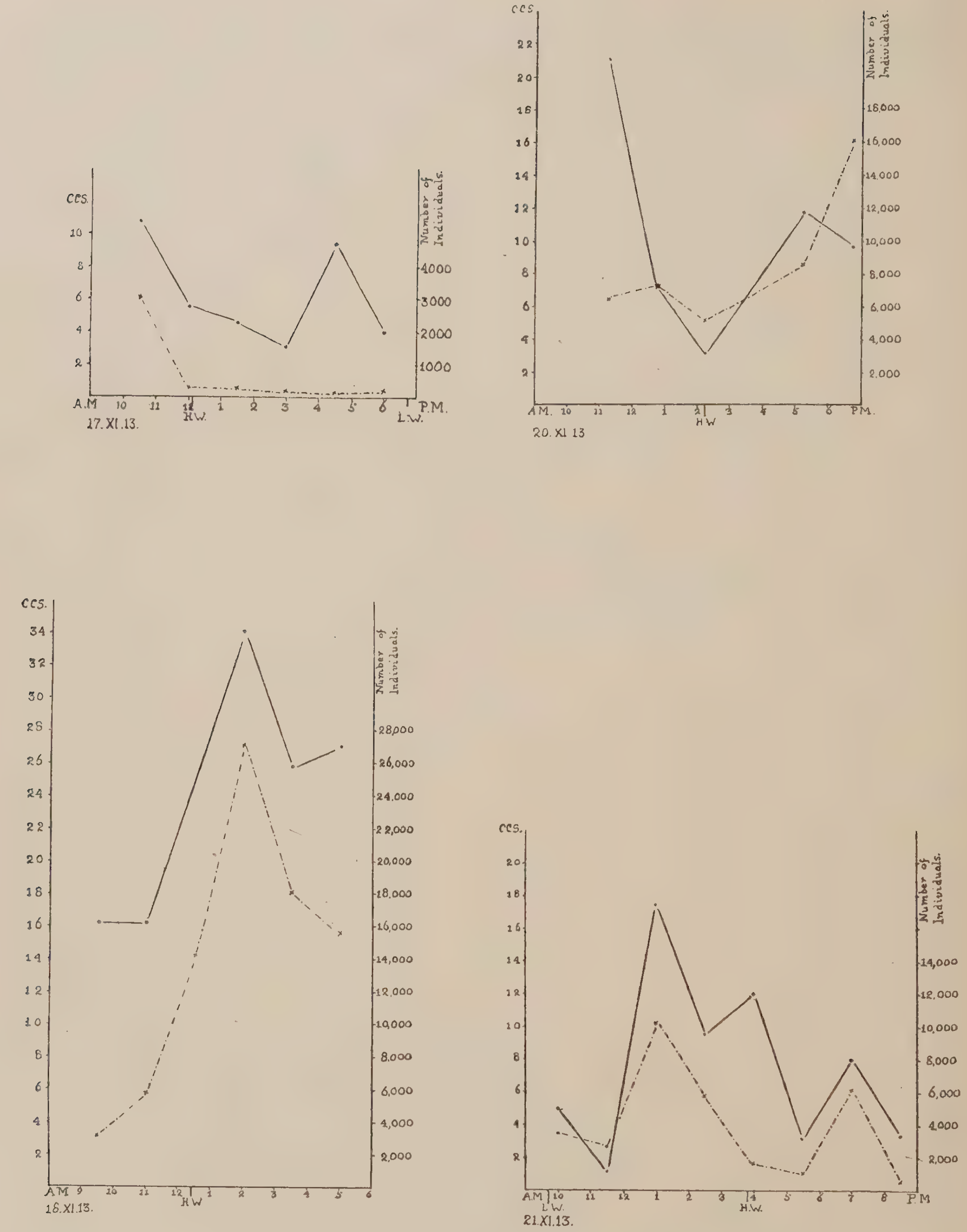
Nikitine (1929) points out that this seasonal migration seems to be determined by temperature. When the temperature of the water rises in summer above a critical point certain species of planktonic organisms descend to a lower and cooler level, and with the advent of winter, as the surface water cools, they ascend again to the surface. *Calanus finmarchicus* (Gunn.) is found in the winter months to leave the surface when the temperature rises above 15° C. and descends to a depth of 90–130 m. In the Black Sea these seasonal movements of *Calanus finmarchicus*, according to Nikitine, coincide almost exactly with the isotherm of + 13° C. In the Mediterranean Sea, Rose (1924) has shown that this species occurs in the superficial stratum in January to April, rarely in May, when the temperature has a mean of 15·37° C. During the rest of the year it is found between 0–70 m. depth, where the temperature is less than 15° C. This critical temperature differs in different species; thus for

Calanus finmarchicus (Gunn.) it is + 15° C.
Oithona similis Claus (adult) ,, + 14° C.
Pseudocalanus elongatus (Boeck) ,, + 13° C.

Centropages kroyeri Giesbr. appears to have a critical temperature of + 17° C., since this isotherm marks the limit of its horizontal range, and hence in the Black Sea it does not exhibit any seasonal migration. It seems possible that the " layering " of individuals of different size and stages of development may largely be the result of differences in the relative density of the animals and the sea water, as suggested by Ostwald. Lowndes (1942) gives the sinking factor of *Calanus finmarchicus* (Gunn.) as 1029 or 1033 at 15·4° C, whereas in *Anomalocera patersoni* Templ., a surface-living form that shows no daily vertical migration, it is as low as 1014, and in *Tigriopus fulvus* (Fischer), a bottom-living form, it is as high as 1060. This sinking factor must vary very considerably during the year, for Bogorov (1934) has pointed out that spring and summer *Calanus* are reddish-yellow and have abundant fat inclusions; winter specimens are greenish-white, and lack fat inclusions or have only very slight ones, presumably owing to reduced winter nutrition: and Marshall, Nicholls and Orr (1934) have shown that there is a marked increase in fat in the body during the months April to September, and that in both male and female *Calanus* the three broods can be recognized by the change in the fat content. Specimens with abundant fat inclusions must possess a lower specific gravity than those without and this may well modify the rate of sinking, and might even abolish any tendency to sink and so cause the individuals to remain near the surface, thus counteracting the tendency to migrate downwards into cooler water during the summer. Gardiner (1931) has pointed out that, subject to certain limitations, " the use of single vertical hauls to study the distribution of the plankton in both space and time may be expected to give reliable results." During my investigations of the "John Murray" collections I made a careful count of the total number of examples of different species that were taken in two hauls at the surface at Station 61, during the day and at night respectively. The results, as regards some of the species, are as follows :

Species.	Day haul.	Night haul.
Nannocalanus minor (Claus)	120	14,280
Calocalanus plumulosus (Claus)	0	1,080
C. pavo (Dana)	240	600
Clausocalanus furcatus (Brady)	120	11,280
Paracalanus aculeatus Giesbr.	0	10,680
P. denudatus Sewell	240	8,280
P. parvus (Claus)	0	2,760
Undinula vulgaris (Dana)	0	240
U. darwini (Lubb.)	0	3,120
Euchæta marina (Prestand.)	0	1,205
E. wolfendeni A. Scott	960	7,086
Euchaeta sp. juv.	720	12,240
Labidocera detruncata (Dana)	120	6,890
Pontellina plumata Dana	0	360
Pontellopsis regalis (Dana)	0	120
Acartia erythræa Giesbr.	0	120
A. amboinensis Carl	120	240
Oithona plumifera Baird	0	1,680
Oncæa mediterranea Claus	4,440	14,160
O. media Giesbr.	6,482	14,040
Corycella gibbula (Giesbr.)	15,485	3,280
? *Corycæus rostratus* Claus	1,560	0
C. gracillicaudatus Giesbr.	360	120
C. speciosus Dana	960	0
C. latus Dana	240	0
? *C. curtus* Farran	240	0
Centropages gracilis (Dana)	1,200	324
C. orsinii Giesbr.	120	120

The day haul was carried out for an hour from about 1.30 p.m. to 2.30 p.m. and the night haul was made between 1.30 a.m. and 2.30 a.m., and the net was of fine silk with a diameter at the mouth of 50 cm., the same net being used for each haul. The total quantity of Plankton taken was 170 c.cs. in the night haul and 52 c.cs. in the day. From the above figures it is clear that many species were much more frequent on the surface during the night, as compared with the numbers taken in the day ; but as regards the genera *Corycæus* and *Corycella* the exact opposite was the case. In these two genera far more examples of six species were taken by day. If these differences between the two hauls are due to migration from one stratum to another, it seems probable that the species of *Corycæus* and *Corycella*, unlike so many other species of the epi-plankton, come up towards the surface by day and sink down to a lower level during the night ; the same seems to hold good for *Centropages gracilis* (Dana). It must, however, be pointed out that during the



Text-fig. 78.—Variations in the total amount of plankton and the number of Copepoda present during the day at "Investigator" Sta. 566, lat. 11° 57′ 30″ N., long. 98° 19′ 00″ E., on 17–18.xi.1913, and Sta. 567, lat. 11° 54′ 00″ N., long. 98° 18′ 45″ E., on 20–21.xi.1913. H.W., high water. L.W., low water. ———— Total plankton in c.c's. – · – · – · – Number of Copepoda.

course of our observations the ship had drifted from lat. 23° 02′ 48″ N., long. 64° 31′ 54″ E. to lat. 23° 02′ 12″ N., long. 64° 33′ 39″ E.; it is thus possible that we were sampling two distinct water-masses.

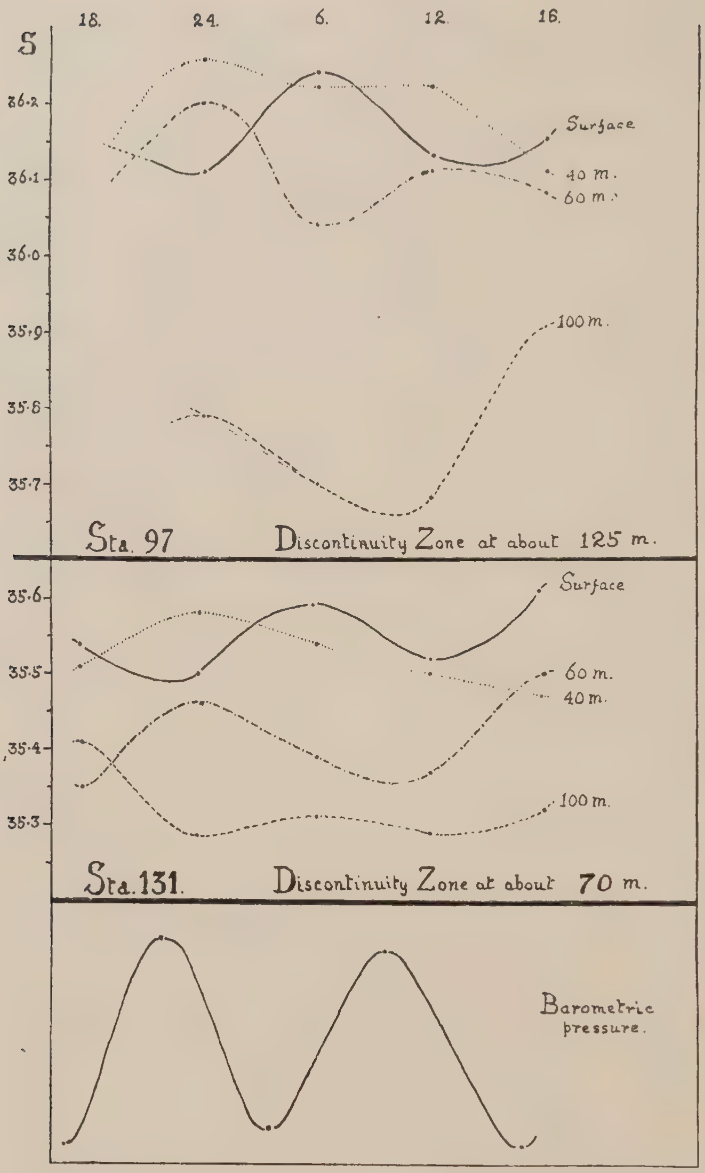
In a series of observations carried out by me in the Mergui Archipelago off the coast of South Burma in 1913 a very great variation in the numbers of Copepoda present in the surface water was detected. In these observations the ship was at anchor, and a silk net was suspended just below the level of the surface and the tidal current allowed to flow through. The net remained down for half-an-hour and the total number of Copepoda captured was counted: at the same time the rate of flow of the current was taken and the number of Copepoda per knot current was calculated. The same net was used throughout. Although the method was crude and made no allowance for the different rate of flow through the net with currents of different strength, it serves to give an indication of the relative richness of the catches at different times of the day. In all four series (*vide* Text-fig. 78) the catch was low between 9 and 11 a.m., rose to a first maximum between 12 noon and 2 p.m., dropped again between 4 and 5 p.m. then rose to a second maximum about 7 p.m., and on the last day sank again to a minimum between 8 and 9 p.m. That this double variation was not due to tidal changes is indicated by the different position of the times of high and low water on the curves on different days; nor can it be attributed to a diurnal migration under the influence of light. There are, however, certain other physical factors that may produce differences in the density of the fauna at any given level, and up to the present time these do not appear to have received the attention that they deserve: such factors are (1) a periodical "change-over" of the surface water under the influence of some factor other than that of heating by solar activity and evaporation, and (2) oscillatory movements of the deeper strata.

As regards the first factor, I have pointed out (Sewell, 1928, p. 186, and 1929, p. 296) that observations taken in the Bay of Bengal and Revello Channel in the Nicobar Islands in the month of October show a clear daily double rise and fall of the surface salinity, alternating with the rise and fall of the barometric pressure, whereas off the west coast of India in April and May we get a similar double rise and fall of the surface salinity now coinciding with the rise and fall of the barometer; this difference is apparently due to the fact that at one season of the year the surface stratum has a higher salinity than that at a lower level and at the other season the reverse is the case, the surface water having a lower salinity than that lower down. Very similar variations were found to be present at Stations 97 and 131 in the Arabian Sea during the "John Murray" Expedition in December, 1933, and February, 1934, respectively. I give the data of these two stations below and the results have been plotted in Text-fig. 79.

Sta. 97, 21.xii.33. Lat. 10° 56′ 18″ N., long. 59° 55′ 24″ E. Salinity ‰.

	Time of day. 21.xii.33.			
Depth in metres.	0.00.	6.00.	12.00.	18.00.
0	36·11	36·24	36·13	36·15
20	36·26	36·26	36·13	36·13
40	36·26	36·22	36·22	36·11
60	36·20	36·04	36·11	36·08
80	36·18	35·93	35·93	35·97
100	35·79	35·70	35·68	35·91

Discontinuity zone at about 125 m. depth.



TEXT-FIG. 79.—Showing the salinity at different depths at different times of the day at " John Murray " Stations 97 and 131.

Sta. 131, 10–11.ii.34. Lat. 1° 39′ 06″ S., long. 61° 13′ 48″ E. Salinity ‰.

Depth in metres.	Time of day.				
	10.ii.34.		11.ii.34.		
	17.30.	23.45.	5.45.	12.00.	17.30.
0	35·54	35·50	35·59	35·52	35·61
20	35·52	35·52	35·53	35·52	35·52
40	35·51	35·58	35·54	35·50	35·47
60	35·35	35·46	35·39	35·37	35·50
80	35·36	35·37	35·31	35·30	35·35
100	35·41	35·28	35·31	35·29	35·32

Discontinuity zone at about 70 m. depth.

For comparison I have given in the figure the rise and fall of barometric pressure. At both stations the salinity on the surface exhibits a clear tendency to alternate with the rise and fall of the barometric pressure. At 40 m. depth in both series the salinity shows a maximum at 24·00 hrs. and then falls steadily to 18·00 hrs. In the series from Sta. 97 at a depth of 60 m. the salinity again shows a double rise and fall during the day that here tends to run with the barometric pressure, having a primary maxima at about 24·00 hrs. and a secondary maximum at about 12·00 hrs.: no such curve, however, is shown at Sta. 131. At this depth at the latter station the salinity exhibits a curve that exhibits two maxima at about 24 hrs. and 18 hrs. If now these changes are due to vertical movements of the water particles under the influence of evaporation or, as I suggested in a previous paper (Sewell, 1928 and 1929), as a result of variations in the wind force, such changes can only affect the stratum above the discontinuity zone, which at Sta. 97 lay at a depth of about 125 m., but at Sta. 131 at about half this depth, namely, 70 m. We should therefore compare the curve at 60 m. depth at Sta. 131 with that at 100 m. at Sta. 97, and it is clear that the two curves are remarkably similar.

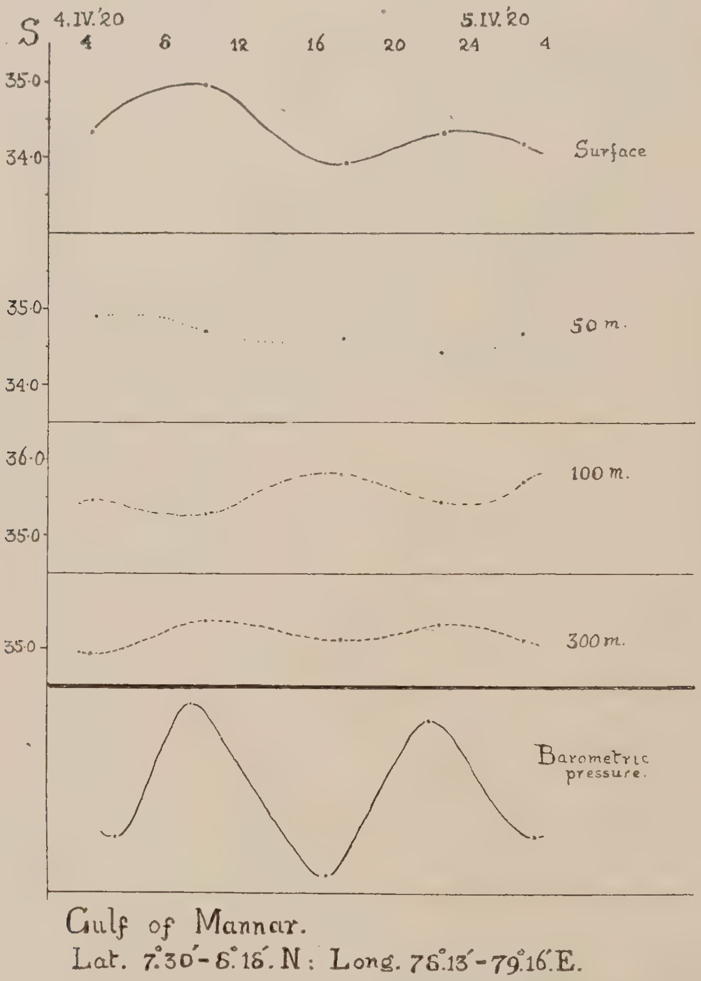
Sets of serial observations taken at standard depths in a single locality at intervals during the day are extremely rare in many regions and are practically non-existent for the Arabian Sea, but Pearson (1922), in the Ceylon Administration Report for 1921, gives several series taken consecutively in different localities but within short distances, and I give his results below:

Gulf of Mannar. 4–5.iv.20. Lat. 7° 30′–8° 18′ N., long. 78° 13′–79° 16′ E. Salinity ‰.

Depth in metres.	Time of day.				
	4.iv.20.				5.iv.20.
	3.37–5.0.	9.50–11.20.	17.18–18.20.	22.10–23.10.	2.28–3.28.
0	34·34	34·00	33·93	34·29	34·23
50	34·99	34·72	34·63	34·45	34·67
100	35·46	35·26	35·53	35·48	35·71
200	35·35	35·23	35·14	35·07	35·32
300	34·90	35·35	35·14	35·32	35·10

There was no evidence of any Discontinuity zone in this area as far down as 300 m., below which no observations were taken. I have plotted these results in Text-fig. 80. Here too we find that the surface salinity exhibits a double rise and fall in 24 hours, but this curve differs from those exhibited at the two "John Murray" stations in that the rise and fall coincides with the barometric changes. At 50 m. depth we again get a slight single daily rise and fall, having its maximum at about 4·0 hrs. At 100 m. depth the salinity again shows a double rise and fall, but this now alternates with the rise and fall of barometric pressure and the salinity on the surface. At 300 m. the salinity still exhibits a slight double rise and fall, but at this depth there has been another change and the curve again follows the barometric pressure. The reason for the difference in the surface curve at this station and those at the "John Murray" Stations is clearly to be found in the fact that here the surface salinity is lower than that at some depth below. It thus seems possible, if not probable, that the double daily rise and fall in the quantity of the surface plankton is correlated with this double daily "change-over" of the surface water under the influence of a double daily rise and fall in the strength of the wind force, but modified and influenced by other factors such as the rise and fall of the tide and variation in the intensity of the sun's rays and the temperature of the surface water.

Somewhat similar oscillations have been recorded in the Gulf of Maine (*vide* Clarke, 1934*a* and 1934*c*), where at a depth of from 10 to over 80 m. the temperature of the water changed very considerably twice in 24 hours, rising to a primary maximum at about 5–6 hrs., with a secondary maximum at about 18 hrs. As Clarke points out, such a change, that at one time was so rapid that the temperature at a depth of 28 m. altered from 7° C. to 12° C. in three hours must have been produced by vertical oscillation of the whole stratum, and this must have carried with it the planktonic population. Seiwell (1937) has also called attention to similar vertical oscillations in the western part of the North Atlantic, and he concludes that these are to a large extent associated with the tidal wave. In a later paper (1939) he states that "continuous temperature measurements at fixed depths over time intervals up to 12 days show average daily vertical displacements of 38 to 227 m., the larger value occurring where the water is least stable." Such vertical displacement of



Text-fig. 80.—Showing the salinity at different depths at different times of the day in the Gulf of Mannar.

the water particles must be accompanied by a similar displacement of the plankton, and hence no explanation of the vertical " migration " of such organisms as the Copepoda can be complete which does not take congnizance of these vertical oscillations and convection currents in the water strata.

Another type of oscillation, differing from the above in that it exhibits a longer " period," has also been noted in various regions and has been attributed to a " seiche " in the deeper stratum, the length of the time period depending on the depth and configuration of the area and the difference in salinity of the upper and lower strata. In several coastal areas round the Bay of Bengal I have shown (*vide* Sewell, 1928, p. 179) that the surface salinity shows a periodic rise and fall, and I have explained this as a result of a " seiche," or swinging of the deeper stratum ; accompanying each rise there was evidence of an increase in the number of planktonic organisms, and in some cases of the appearance of organisms that were normally absent ; this I attribute to a mixing of the water of the lower stratum with that of the surface layer by wave action when the lower stratum approaches sufficiently near to the surface to be affected. It thus seems possible that variations in the number of organisms present at any given level in any area may be due, not to active migration of the organisms themselves, but to purely passive movement brought about by changes in the level or the character of the stratum of water in which they are living.

Russell (1931) suggested that the upward migration of planktonic organisms that seems to be so frequently met with in the Plymouth and other regions may be impeded by obstructing animals, large numbers of other animals in the plankton causing a modification of the behaviour to be expected. Hardy and Gunther (1935) have put forward the view that a dense phytoplankton population has an excluding influence on the smaller zooplankton. They point out that, with few exceptions, where the phytoplankton is dense, zooplankton is scanty and appears to be able to avoid such patches. They remark that " the smaller members of the zooplankton, the Copepoda, the Pteropoda, to say nothing of the Foraminifera, obviously could not make such swimming migrations ; yet our results suggest that they have the power of distributing themselves horizontally in relation to the phytoplanktonic production in the upper layer. The power of vertical migration, which so many of these organisms possess, would seem to be their means of ' navigation '." The authors discuss the causation of this departure from the usual habit of the plankton to come up to the surface at night and sink down to a deeper level by day ; and they conclude that the agency does not seem to be mechanical, but is probably chemical, and acts by altering the rate, extent (spatially) and length of time of the vertical migration ; and they have suggested a number of factors, such as the length of time required to obtain a full meal, alterations in the pH of the water causing a change from negative to positive phototropism, the effect of higher O_2 concentration, etc., but they have not considered the possibility that a dense phytoplankton may render the water more viscid, and so may affect the daily " change over " of the water strata. Whatever the causative agent, by altering their level the zooplankton may be brought into a current moving more slowly than the surface water or even moving in a different direction, and so get carried away from the dense phytoplankton patch.

Redfield (1941, p. 96), when studying the influence of the water circulation on the distribution of the Calanoid Copepoda in the Gulf of Maine, has also pointed out that since several species exhibit a well marked diurnal migration, " the population cannot be identified exclusively with any particular layer, and any attempt to correlate its distribution with the drift of the water is complicated by the undoubted migration of the animals to and from layers of different depth moving with different velocities and in some places without doubt in different directions." If such a vertical migration can be brought about at great depths, it will serve to convey the organism from one mass of water into another of entirely different origin, as, for instance, from the surface water, or " troposphere " of Defant, into the uppermost stratum of the " stratosphere," namely the Antarctic intermediate water. In a few instances evidence has been obtained that a vertical migration may be carried out in considerable depths ; thus Esterly (1911*a*) obtained evidence that seemed to him to indicate thet *Eucalanus elongatus* (Dana) carried out migration that resulted in a concentration of individuals at a depth of about 366 m. (200 fms.) by day and a general dispersal at night. Hardy and Gunther (1935) give evidence that tends to show that in Antarctic waters the species *Scolecithricella minor* (Brady) carried out a vertical daily migration as deep as from 500 to 700 m. Welsh, Chace and Nunnemacher (1937) have also obtained some evidence that in the western region of the North Atlantic the copepoda living at a depth of 400 m. show a similar daily vertical migration, so that here too it may be that at least certain species by such migration pass from the upper surface water into the North Atlantic intermediate water, or *vice versa*. It is also probable that along the boundary zone between two water masses moving in different directions, vortices will be set up that will transfer some of the plankton from one water mass to the other, and it is obvious that any such transfer may have a profound effect on the geographical distribution, if the species is capable of surviving in its new habitat.

Damas (1905) asks, How does the plankton of a given region maintain its character in the face of the continual circulation of the currents, and how does a given species persist so as to possess a special geographical distribution ? He concludes that there must exist a special zone or centre of production in which adults abound and reproduce successfully, and that around this region there is a circulatory current. He remarks, " L'existence d'une zone spéciale où abondent les adultes, zone qui se continue directement dans la région la plus riche en oeufs, larves et jeune individus, indique que l'espèce se maintient grâce à l'existence dans ces régions d'un courant circulatoire qui ramène périodiquement une certaine proportion des individus répandus à la surface de l'Ocean et entrainés dans la mouvement continuel des eaux." Damas envisaged a horizontal circulation, but a further possibility is that a certain proportion of a species may by vertical migration reach a different stratum of water from that in which they were originally living, and this new stratum may be flowing in the opposite direction to the current that is carrying them away from their breeding ground or general habitat ; as a result, either the young or the adults of the succeeding generation may be swept back to their original position. It is well known that many species of copepods may ascend to higher levels when spawning, so that the young forms are met with in strata above that in which the adult is usually found. With (1915, p. 28) remarks, " It seems to be a general rule that the younger the stage of development, the nearer the surface do the specimens live, as pointed out by Damas, Paulsen and Farran."

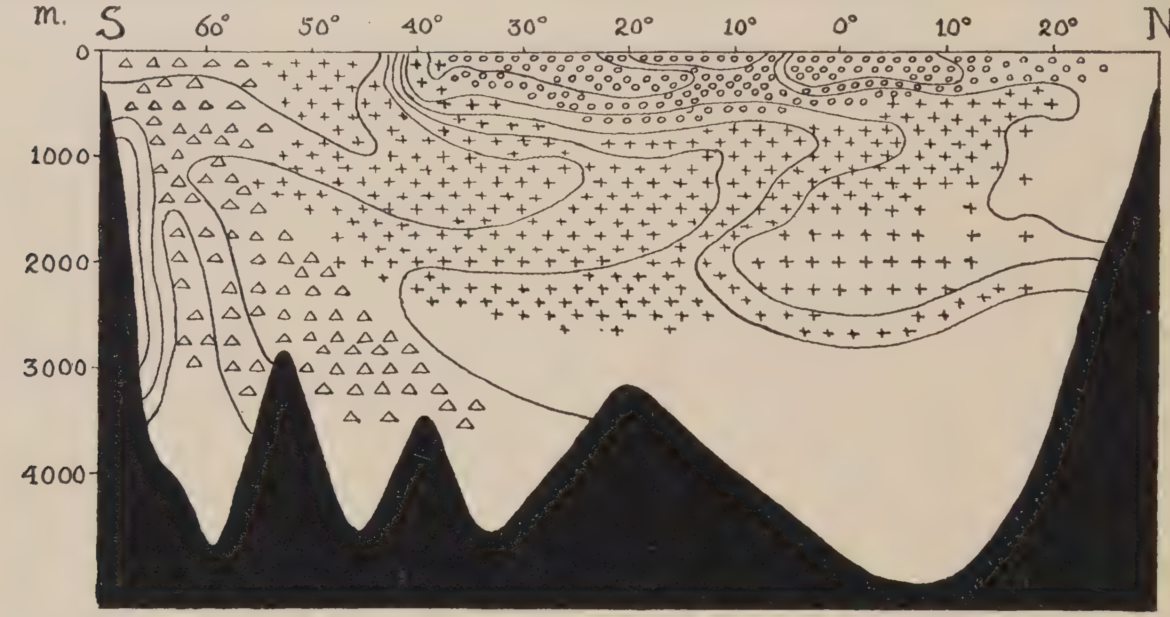
This rule is certainly not universal, for in certain species and in different localities the position of adults and young stages may be reversed. Störmer (1929) has shown that in the sub-arctic region of the North Atlantic the young stages of both *Calanus finmarchicus* (Gunn.) and *Pseudocalanus elongatus* (Boeck) (= *P. minimus*) occur at a higher level than the adults; whereas in the case of *Paraeuchæta norvegica* (Boeck) in this region the young stages were found occupying a lower level than the adults, and With (1915, p. 65) also notes that as regards the form of *Pseudocalanus elongatus* (Boeck), known as *P. gracilis*, the adults were found to be common at depths between 480 and 800 m., whereas the young stages were met with between 800 and 1000 m. Wolfenden (1904) and With (1915) agree that the young forms of *Paraeuchæta norvegica* (Boeck) in the North Atlantic and the region round Greenland are not uncommon at or near the surface, while the adults are in the deeper strata from 914–1097 m. (500–600 fms.). In the catches of the "John Murray" Expedition in the Arabian Sea I have already pointed out (*vide supra*, p. 328) that the young stages of certain species occurred at a higher level than the adults.

	Upper level of appearance of—	
Species.	Young stages (m.)	Adults (m.)
Undeuchæta bispinosa Esterly	100	300
Euchirella galeata Giesbrecht	100	400
Pleuromamma abdominalis (Lubb.)	200	400
Pseudochirella magna (Wolf.)	300	400 to 645
Onchocalanus trigoniceps Sars	600 to 650	850
Bathycalanus bradyi Wolf.	1500	2500

Such differences as these suggest that the adults and young are respectively inhabiting different strata of water, such as the surface stratum and the Indian Intermediate current or the Intermediate current and the Antarctic Bottom Drift.

Schmaus and Lehnhofer (1927, p. 392, figs. 28 and 29) have given charts of the distribution of the genus *Rhincalanus* in the Atlantic and Indian Oceans; unfortunately in their chart of the Atlantic region they have attempted to correlate the distribution with the scheme of the deep currents suggested by Schott (1902, p. 164, fig. 33), in which he postulated intermediate currents from both poles flowing towards the equator and there combining to form an ascending mass of water. They thus show *Rhincalanus nasutus* as occupying two quite distinct regions in the North and South Atlantic Oceans respectively, and between these a gap extending from approximately lat. 10° N. to 10° S., in which no examples are said to be found. The later work of Steuer (1931*b*) has indicated that in the Atlantic Ocean this species inhabits in the main the North Atlantic Intermediate water, but is absent from the western part of the South Atlantic. In Text-fig. 81 I have attempted to indicate the distribution of the species of this genus in the Indian Ocean *Rhincalanus cornutus* Dana, f. *typica*, like f. *atlantica* in the Atlantic Ocean, is an inhabitant of the upper surface stratum or troposphere, and its distribution can be accounted for by horizontal water movements: *R. nasutus* Giesbr. possesses a distribution that comprises in its upper portion the water mass of the Sub-polar or Antarctic intermediate stratum and in its lower region the Indian intermediate current; thus the young stages, inhabiting the upper levels of its distributional area, will be swept from south to north, while the adults, inhabiting the deeper levels, will be carried southwards. The third species, *Rhincalanus gigas* Brady, has a distribution that extends throughout the Antarctic region and the Antarctic bottom water in both the Atlantic and Indian Oceans, but, at any rate in the Indian Ocean, its distributional area comprises in its upper part a portion of the Indian intermediate current, and in consequence the young stages will be swept southwards towards the South Pole while the adults in the lower level will be carried northwards. Hardy and Gunther (1935, p. 356), in their work in the Antarctic region, obtained evidence that they interpret as showing that the species *Scolecithricella minor* (Brady) experiences a similar transference : " It appears that these animals, on being carried by the surface layer to the limit of the Antarctic zone, may descend, as a balloonist would from one air current to another, and make use of the great oceanic current system to return into the Antarctic zone again in the intermediate layer, flowing back towards the Pole." I have already referred to Macintosh's work on *Rhincalanus gigas* Brady (*vide supra*, p. 356).

In attempting to trace the geographical dispersal of these planktonic forms it is essential that one should take a wide view of what constitutes a species, and one must also bear in mind that the adaptability to new conditions may vary greatly. Runnstrom (1927) has pointed out that certain forms during their development are limited to a particular fixed temperature range, which is for that species a physiological constant and, consequently, such species are limited to a fixed area of distribution ; but that in other species a greater range may be tolerated, and these species may evolve into physiological races adapted for life in different conditions, and hence may possess a wide geographical range. Appellöf (1910) and Störmer (1933) have further pointed out that we may get one or more such physiological races within the limits of the same morphological species, or, as Störmer puts it, " we cannot always regard the morphologically determined species as being physiological units in the geography of animals." We may during the course of evolution get a series of stages passing from a single morphological and physiological species, through a morphological species with several physiological races, and then by slight differences of structure to a species in the wide sense with several morphologically distinct races or forms, and finally to distinct but very closely related species.



Text-fig. 81.—The distribution in the Indian Ocean of the species of the genus *Rhincalanus*.
○ *Rhincalanus cornutus*. + *R. nasutus*. △ *R. gigas*.

It has for a long time been recognized that the average size of examples of a given species tends to vary in different localities in which they are living, and that this is in all probability due to differences in the local conditions. At the present time our knowledge of the conditions in many of the areas in which collections have been made is not sufficient to enable us to assign such differences as have been noted to any one specific causative agent, and it is probable that a number of different factors are implicated. Murray and Hjort (1912, p. 693) remark, " First of all, in organisms which cannot lower their specific gravity by depositing fats or absorbing water, we find a dominant tendency to develop minute forms in specifically light water," and Steuer (1923, pp. 38 *et seq.*), reviewing our knowledge up to the time of writing, emphasizes that " im leichten Wasser das Körpervolumen sich verringert, im schweren Wasser sich vergrössert."

I have already given a table showing the range of salinity that is tolerated by certain species living on the coast of Burma (*vide supra*, p. 325), and I give below a few examples of the extreme range of salinity that is tolerated by certain other species :

Species.	Extreme range of salinity ‰.
Acartia clausi Giesbr.	Freshwater to 36·00
A. bifilosa Giesbr.	0·30 ,, 32·00
Pseudodiaptomus tollingeræ Sewell	0·17 ,, 11·84
P. annandalei Sewell	0·17 ,, 18·94
P. binghami Sewell	0·17 ,, 18·94
Temora longicornis Müll.	6·54 ,, 36·16
Acartia longiremis (Lübb.)	6·72 ,, 35·32
Pseudocalanus elongatus Boeck	7·25 ,, 35·30
Pseudodiaptomus serricaudatus (T. Scott)	10·85 ,, 43·80
Centropages hamatus (Lillj.)	13·5 ,, 23·90
Oithona nana Giesbr.	13·68 ,, 43·80
Labidocera pavo Giesbr.	14·12 ,, 32·00
Paracalanus parvus (Claus)	19·33 ,, 43·80
Metridia lucens Boeck	28·10 ,, 35·40
Calanus finmarchicus (Gunn.)*	29·00 ,, 35·30
Acrocalanus gibber Giesbr.	32·95 ,, 35·50

Where a wide range of salinity is tolerated one would expect to find differences in size, and in some species these have been recorded, as, for instance, in the following :

Species.		Locality.	Total length. (mm.)
Acartia clausi Giesbr.	♀,	Brackish water	0·70–0·83
		North Sea	1·47
	♂,	Brackish water	0·71–0·82
		North Sea	1·31
Acrocalanus gibber Giesbr.	♀,	Bay of Bengal	0·81
		Bitter Lakes, Suez Canal	0·86

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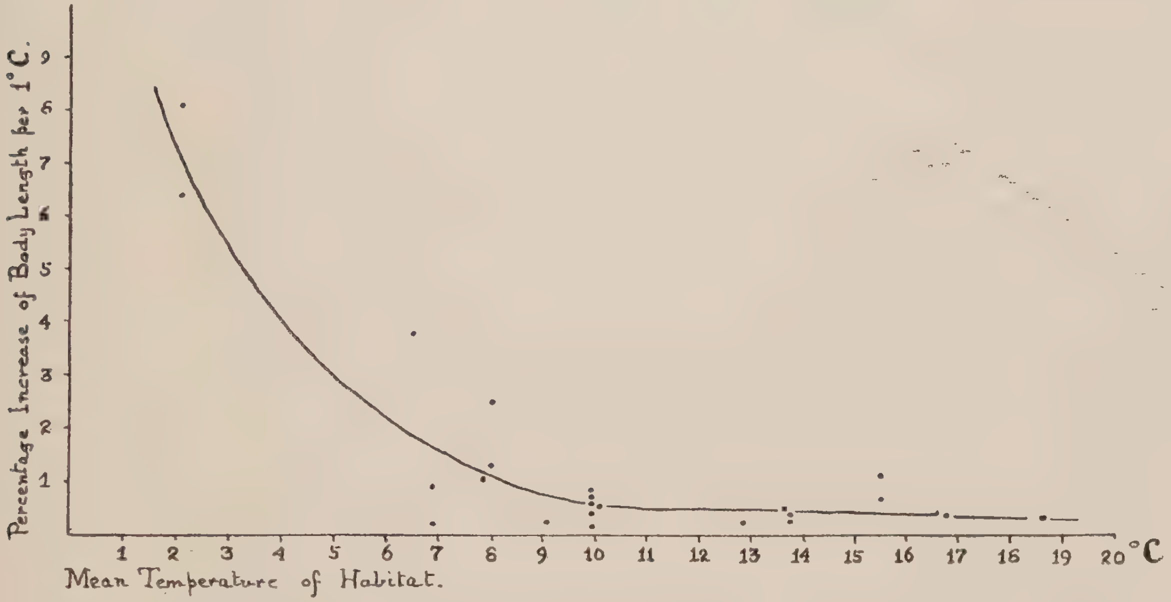
* Stalberg (1931) has recorded the presence of a variety of *Calanus finmarchicus*, which he has named *teleykensis*, in the Teleyker Sea in Altai, in water of low salinity, 60·8 mg. per litre.

Labidocera pavo Giesbr.	♂,	Indian Ocean	1·12–1·20
		Red Sea	2·12
Centropages tenuiremis Thomp. and A. Scott	♀,	Gulf of Aden	1·50
		Puri, Bay of Bengal	1·71
		Ceylon Pearl Banks	1·80
	♂,	Puri, Bay of Bengal	1·43
		Gulf of Aden	1·50
		Ceylon Pearl Banks	1·80

But in most instances a difference in salinity between two localities is accompanied by other changes in the local conditions. A change of salinity alone, in so far as this is produced in the ocean by evaporation or by dilution with rain-water, will merely affect the density of the water in which the animal is living, and hence will expedite or retard the rate at which the individual tends to sink or rise according to whether the density of the surrounding medium is below or above that of the animal itself. A change of temperature, however, will produce a two-fold effect: it will, like a change in salinity, alter the density of the medium, but at the same time it will act directly on the organisms accelerating or retarding the vital processes, according as the temperature rises or falls, and thus will affect the length of life of the organism, the time of onset of maturity, and hence, perhaps, the size to which it will grow: but experiments carried out by Coker (1933) on *Cyclops vernalis* Fischer throw some doubt on this last point. Coker remarks that "our general observations on several species of Copepoda does not at all bear out the supposition of a causal relationship between the length of the period of development and the greater size at maturity." It is, however, now well recognized that in any given locality in which there is a well-marked seasonal variation in temperature we find an equally well-marked seasonal change in the size of individuals of any given species, if these have more than one generation in the year. The seasonal changes in size and body-mass of *Calanus finmarchicus* (Gunn.) have been studied by Bogorov (1934), who has given numerous references to earlier work on this subject; he summarizes his conclusions as follows: "A definite relation is obvious between size of organism and hydrological conditions, the main factor being temperature, particularly during the period of development. Thus the large sized 'spring' generation was hatched at 8°–9° C. of temperature; the smaller 'summer' generation at 10·5°–14·5° C.; the very smallest 'autumn–winter' generation at the warmest temperature of 15°–16° C." Thus during the course of a year one form gives rise to another, this phenomenon being known as "cyclomorphosis." Bogorov agrees with the conclusion drawn by Adler and Jespersen (1920) that the size attained is inversely proportional to the temperature in which the individual was living during its development. Jespersen (1937) has shown that the arctic Calanoid, *Calanus hyperboreus* Kröyer, also exhibits certain variations in size, and that "a comparison between the average length of *Calanus hyperboreus* and the hydrological conditions at the different stations shows distinctly that the temperature is an important factor," and that "the smallest sizes of this copepod are found in waters mixed with that from the Atlantic having temperatures above 3° C., while the larger sizes predominate in water with a negative temperature and up to 1·2° C. Furthermore, it is of interest in this connection to draw attention to the fact that the distribution of the large sizes of *Calanus hyperboreus* is in all essentials identical with the areas of West Greenland waters where the large individuals of *Calanus finmarchicus* predominate." Steuer (1937) has given the results obtained from a study of the material obtained in the Atlantic Ocean by the "Meteor," and here too he has found that the size attained by individuals of the species *Pleuromamma abdominalis* (Lubb.) f. *typica* and *Pleuromamma robusta* (F. Dahl) varies with the temperature of the water, and especially of the water at a depth of about 100 m. Bogorov (1934), from his study of the bio-mass of individuals of the same species under different temperature conditions, reached the conclusion that "the value of the difference in temperatures depends on its place on the temperature scale, the influence of smaller differences in temperature under lower conditions having a greater effect than large differences at higher temperatures." In order to see how far the present series agrees with this finding, I have in a number of species calculated the percentage increase in the total body-length for every change of 1° C. in the temperature, and the results are given in the following table.* In the majority of cases the size differences are taken from a number of individuals captured at the same station but at different depths, but in a few instances the measurements are of specimens taken at different depths at different stations. In the accompanying figure (Text-fig. 82) I have plotted the percentage increase in the total body-length for each 1° C. difference in the temperatures of the habitats against the mean temperature at which the individuals were living, and the result thus obtained certainly appears to indicate that throughout the range of temperature from 20° to 10° C. there is only an extremely small increase in size, but that below 10° C. the percentage increase in length goes up rapidly.



TEXT-FIG. 82.—Showing the percentage increase in the total body-length for each 1° C. difference in the temperature of the habitats at different temperatures.

That variation in temperature is not the only factor affecting the size of the organism is clear from the different results that have been observed in different localities. Rzoska (1932) has shown that at a high altitude *Cyclops strenuus* Fischer exhibited a variation in size that coincided with the change in temperature, specimens being larger in summer and

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* In addition to my own observations I have included those made by Bogorov (1934) on *Calanus finmarchicus*, by Sömme (1929) on *C. hyperboreus*, and by Steuer (1937) on *Pleuromamma robusta.*

Temperature interval. (° C.)	Range. (° C.)	Mean temperature. (° C.)	Size variation. (mm.)	Difference. (mm.)	Increase $^{\circ}/_{\circ\circ}$ per 1° C.	Species.
4·7 to − 0·5	5·2	2·1	3·22 –4·57	1·35	8·06	*Calanus finmarchicus* (Gunn.).
4·7 ,, − 0·5	5·2	2·1	6·0 –8·0	2·0	6·40	*C. hyperboreus* Kröyer.
8·7 ,, 4·38	4·32	6·5	4·9 –5·7	0·80	3·78	*Gætanus kruppi* Giesbr.
9·5 ,, 4·38	5·12	6·9	4·97 –5·37	0·40	1·65	*Pleuromamma xiphias* Giesbr.
9·5 ,, 4·38	5·12	6·9	4·275–4·319	0·044	0·21	,, ,, ,,
11·5 ,, 4·38	7·12	7·94	6·25 –6·718	0·468	1·05	*Lophothrix frontalis* Giesbr.
11·27 ,, 8·69	2·58	9·98	5·219–5·315	0·096	0·71	*Eucalanus elongatus* (Dana), adult.
11·27 ,, 8·69	2·58	9·98	4·366–4·445	0·079	0·61	,, ,, ,, Stage V.
11·27 ,, 8·69	2·58	9·98	3·424–3·460	0·036	0·41	*Rhincalanus cornutus* Dana.
11·27 ,, 8·69	2·58	9·98	3·794–3·875	0·081	0·83	*Eucalanus pseudattenuatus* sp. nov.
11·27 ,, 8·69	2·58	9·98	4·430–4·520	0·090	0·79	*Pleuromamma xiphias* Giesbr.
12·5 ,, 8·7	3·8	10·6	5·143–5·254	0·111	0·57	*Lophothrix frontalis* Giesbr.
12·38 ,, 5·75	6·63	9·06	4·198–4·264	0·066	0·24	*Rhincalanus nasutus* Giesbr.
11·27 ,, 8·69	2·58	9·98	4·221–4·235	0·014	0·13	,, ,, ,,
14·0 ,, 11·77	2·23	12·88	2·268–4·292	0·024	0·25	*Pleuromamma xiphias* Giesbr.
14·0 ,, 2·0	12·0	8·0	3·32 –4·32	1·00	2·52	*P. robusta* (Dahl), ♀.
14·0 ,, 2·0	12·0	8·0	3·11 –3·59	0·48	1·28	,, ,, ♂.
14·59 ,, 12·69	1·90	13·64	4·212–4·252	0·040	0·50	*Rhincalanus nasutus* Giesbr.
16·27 ,, 11·27	5·0	13·77	3·353–3·424	0·071	0·42	*R. cornutus* Dana.
16·27 ,, 11·27	5·0	13·77	4·160–4·221	0·061	0·29	*R. nasutus* Giesbr.
25·0 ,, 6·00	19·0	15·5	3·11 –3·53	0·42	0·71	*Pleuromamma robusta* (Dahl), ♀.
25·0 ,, 6·00	19·0	15·5	2·68 –3·28	0·60	1·18	,, ,, ,, ♂.
26·0 ,, 11·35	14·65	18·67	3·204–3·378	0·174	0·37	*Rhincalanus cornutus* Dana.
27·8 ,, 5·75	22·05	16·77	3·618–3·955	0·337	0·42	*Eucalanus pseudattenuatus* sp. nov.

smaller in winter, whereas at low altitudes both this species and *Cyclops vicinus* Ulj. showed a variation alternating with the temperature, examples being larger in winter and smaller in summer. To account for the differences in size of *Sagitta elegans* Verrill and *Sagitta setosa* J. Müller in the Plymouth area, Russell (1932, p. 136) has suggested that "it is probable that the size reached is conditioned amongst other things by the amount and type of food eaten, the temperature conditions and the length of life, and that the latter depends on the time of onset of maturity," but Coker (1933) in his experiments on *Cyclops vernalis* Fischer, to which I have already called attention, found that though deficiency of food-supply may cause a retardation or even arrest of development, it does not appear to have any effect on the size attained.

That factors other than temperature may effect the size of individuals is also indicated by Marshall (1933), who states that in *Calanus finmarchicus* (Gunn.) in the Clyde Sea-area "in general the size was greatest when the water temperature was low, and least when it was high, but beside this there was a series of increases and decreases in size, which were apparently connected with the breeding periods." In a previous paper (Sewell, 1934*b*) I showed that in a natural fresh-water environment in India two species of Calanoids, *Diaptomus viduus* Gurney and *D. contortus* Gurney, and two species of Cyclopoida, *Cyclops leuckarti* (Claus) and *C. rylovi* Smirnov, exhibited a double size variation during the year, a primary maximum occurring during the cold winter months, December–January, and a secondary maximum during the hot months, April–June ; and between each maximum is a corresponding minimum. I pointed out that "the chief increase in reproductive activity seems to correspond with the period during which we find the maximum increase in the general size of the individual."

Since a number of factors appear to be involved, it is not surprising that in many species we find very considerable differences in the size of individuals taken in different localities, and I give below a few examples :

Species.	Total length in mm.		
	Atlantic Ocean.	Indian Ocean.	Pacific Ocean.
Eucalanus crassus Giesbr.	3·4 –3·6	3·0	3·0
E. subtenuis Giesbr.	2·65–3·4	2·03	2·7
Euchæta marina (Prestand.)	2·24–4·0	3·0–3·68	3·0–5·0
Lucicutia flavicornis (Claus)	1·47–1·58	1·47	1·60
Labidocera detruncata (Dana)	3·0	2·81	2·25–2·80
Bradyidius armatus (van Höffen)	2·4	1·2	. .
Disseta palumboi Giesbr.	6·36–7·0	7·0	5·7–8·3
Euaugaptilus longimanus Sars	5·3–5·8	9·5	. .

It is also now well known that in many species examples taken at different depths may exhibit differences in size, those from higher levels being smaller than those from deeper down. This difference in size is usually given as the explanation of the fact that in most species the males, which are smaller than the females, are to be found at a higher level. Here too it seems probable that more than one factor is involved, for experiments conducted by Coker (1929) on *Cyclops vernalis* Fischer reared in the laboratory showed that "males greatly predominate in cultures reared at high temperatures, females in those reared at low temperatures, with no regularity of predominance at intermediate temperatures."

Thus it may be that the increase in the number of males in a higher stratum than that occupied by the majority of the females may possibly be in part due to the effect of higher temperature on development, causing a majority of the ova in the warmer layer to develop into males, and not be due to any correlation between the size of the individual and the density of the water. Steuer (1931) has given the depth distribution of the various species in the two genera, *Rhincalanus* and *Copilia*, and he has shown that in the former genus the males are smaller than the females and are found to inhabit a higher level, whereas in *Copilia* the converse is the case, the males being larger than the females and occurring in deeper strata. Even in members of the same sex, differences can be detected in examples taken from different depths in the same locality. Clarke has noted such differences in examples of species taken in the upper levels of the sea, and he gives a table showing the results of his measurements, which I reproduce below :

Length measured Cephalothorax (excluding Abdomen), to end of Lateral Spine, if present.

Metridia lucens Boeck.

Depth. (m.)	Average size, ♂. (mm.)	Average size, ? sex. (mm.)
42	1·296	1·466
78	1·342	1·458
114	1·356	1·583

Calanus finmarchicus (Gunn.).

Depth. (m).	Adult. ♀.	Stage V.	Stage IV.	Stage III.
6	2·445	2·152	1·664	1·263
42	2·589	2·305	1·707	..
114	2·766	2·328	1·787	..

With (1915) considers that *Pseudocalanus elongatus* Boeck, *gracilis* Sars and *major* Sars are in reality examples of the same species, and that such differences as have been noted are due to the different depths at which the examples were living :

Pseudocalanus elongatus Boeck,	length 1·40 mm.	near the surface.
P. gracilis Sars,	,, 1·65 ,,	at 600 m. depth.
P. major Sars,	,, 2·4 ,,	at 800–1350 m. depth.

Farran (1926) described from the Bay of Biscay two forms of *Spinocalanus abyssalis* Giesbr., f. *typica* and f. *pygmæus* ; both forms appear to have a depth range of from 200–1000 m., but Farran suggests that the smaller form, *pygmæus*, has its optimum at a somewhat higher level than the larger, namely from 300–500 m. In the "John Murray" Expedition a sufficient number of examples of a few species were taken at different depths, and I have measured these and have calculated the average length of the individuals of each catch. I give these results below, and for each catch I have given the estimated depth at which the haul was made and the approximate temperature of the water at that depth. It must, however, be borne in mind that the given depth can only be regarded as approximate, for the nets used were not, with very few exceptions, self-closing. Usually the nets were lowered to the required depth, and they were then hauled, as far as was possible, horizontally for an hour and then were hauled to the surface, fishing all the way. The records of the Depth-recorder, attached to the net, showed that the depth of the net during a haul varied very considerably.

Species.	Sex.	Sta.	Average depth of haul in metres.	Temperature. (°C.)	Average length. (mm).
Rhincalanus cornutus (Dana)	♀	172	200	16·27	3·354
			400	11·27	3·424
			850	8·7	3·464
	♀	96	10	26·08	3·204
			645	10·5	3·378
Rhincalanus nasutus Giesbr.	♀	76	600	12·38	4·198
			1500	5·75	4·264
	♀	172	200	16·27	4·160
			400	11·27	4·221
			850	8·68	4·235
	♀	186	250	14·6	4·212
			600	12·69	4·252
Eucalanus attenuatus (Dana)					
Adult	♀	172	400	11·27	5·219
			850	8·68	5·315
Stage V	♀	172	400	11·27	4·366
			850	8·68	4·445
Adult	♂	172	400	11·27	4·027
			850	8·68	4·101
Stage V	♂	172	400	11·27	4·019
			850	8·68	4·101
Eucalanus pseudattenuatus sp. nov.	♀	61	10	27·8	3·618
			1000	9·0	3·843
			1500	5·75	3·845–3·955
		172	400	11·27	3·797
			850	8·68	3·875
Pleuromamma xiphias (Giesbr.)					
f. *minor*	♀	131	500	9·5	4·275
			1500	4·38	4·319
	♀	172	400	11·27	4·430
			850	8·69	4·520
	♂	172	400	11·27	4·759
			850	8·69	4·618
	♀	186	600	14·0	4·268
			950	11·77	4·292
	♂	186	600	14·0	4·558
			950	11·77	4·547
f. *major*	♀	131	500	9·5	4·967
			1500	4·38	5·379
	♂	131	500	9·5	5·017
			1500	4·38	5·554

It is interesting to note that in some species the rule that a lower temperature is correlated with an increase in size appears not to hold good, as for instance in the males of *Pleuro-*

mamma xiphias f. *minor* at Stas. 172 and 186. If now we contrast examples taken at different stations and arrange the length measurements according to the temperature in which they were living at these different stations, we get the following results :

Rhincalanus cornutus (Dana).

	Temperature. (°C.)	Average depth of haul in metres.	Sta.	Average length. (mm.)
♀	26·08	10	96	3·204
	16·27	200	172	3·353
	14·0	575	186	3·368
	12·12	645	96	3·378
	11·27	400	172	3·424
	9·67	500	131	3·349
	8·7	850	172	3·464

Rhincalanus nasutus Giesbr.

♀	16·27	200	172	4·160
	14·59	250	186	4·212
	12·69	500	186	4·252
	12·38	600	76	4·198
	11·27	400	172	4·221
	8·68	850	172	4·235
	5·75	1500	76	4·264

Eucalanus attenuatus (Dana).

				Stage V.	Stage VI.
♀	27·8	10	61	4·161	..
	12·59	600	186	4·301	4·954
	11·27	400	172	4·366	5·219
	10·4	645	96	4·245	5·113
	9·67	500	131	4·080	..
	8·68	850	172	4·445	5·315
♂	27·8	10	61	3·069	..
	12·59	600	186	3·987	..
	11·27	400	172	4·019	4·027
	10·4	645	96	3·972	3·900
	9·67	500	131	..	..
	8·68	850	172	4·101	4·101

Pleuromamma xiphias (Giesbr.) f. *minor*, adult.

			♀.	♂.
14·0	600	186	4·268	4·558
11·77	950	186	4·292	4·547
11·27	400	172	4·430	4·759
9·5	500	131	4·275	..
8·69	800	172	4·520	4·618
4·38	1500	131	4·319	..

While on the whole the average length shows a steady increase with a fall of temperature, it is clear that at certain depths and at certain stations the size of the examples taken was smaller than one would expect. These localities are at Sta. 76, depth 600 m., Sta. 96, depth 645 m., and Sta. 131, depths 500 and 1500 m. It thus seems probable that in these localities there is some factor other than temperature that is affecting adversely the rate of growth. A study of the hydrographic conditions at these stations 76, 96 and 131 shows that in each case at the depth indicated examples were living in the mass of water that forms the Indian intermediate current and is characterized by a marked deficiency of oxygen-content (*vide infra*, p. 535).

If, as is believed, the temperature of the water in which individuals are living is the main factor in the production of variation in size and that the effect is produced during development, it follows that we should, in those localities that exhibit a seasonal variation in temperature at the depths concerned, be able to trace a corresponding variation in the total length of specimens taken at approximately the same depth in different months of the year. Such evidence as I possess is not sufficient to demonstrate this beyond any possibility of doubt, but I give below tables of data in regard to two species that appear to indicate that such variation is to be found, but that the effect on the body-length does not occur simultaneously with the change of temperature, but after an interval of time, the length of which differs at different levels, those species that inhabit less deep water, and so are living at a somewhat higher temperature, exhibiting a shorter time lag than those that live in deeper and colder water.

Eucalanus pseudattenuatus sp. nov.

	Month.	Approximate temperature at 200 m. (° C.)	Total length. Stage V. (mm.)	Total length. Stage VI. (mm.)	Month of capture.
♀	October	17·0	3·000–3·333	3·618–3·955	November.
	November	16·3	3·315	3·888	December.
	December	15·0	..	..	January.
	January	13·0	3·322	4·000	February.
	February	14·3	3·050	3·600	March.
	March	13·5	3·300–3·316	3·794–3·875	April.

Eucalanus attenuatus (Dana).

		200 m.	400 m.			
				4·161	..	November.
				4·245	5·113	December.
♀	October	12·0	10·25	..	..	January.
	November	12·1	10·65	4·08	..	February.
	December	11·2	10·5	..	..	March.
	January	10·5	8·2	4·366–4·445	5·219–5·315	April.
	February	10·5	8·8	4·301	4·954	May.
				3·069	..	November.
				3·972	3·950	December.
♂	October	12·0	10·25	..	..	January.
	November	12·1	10·65	..	..	February.
	December	11·2	10·5	..	..	March.
	January	10·5	8·2	4·019–4·101	4·027–4·101	April.
	February	10·5	8·8	3·987	..	May.

In *Eucalanus pseudattenuatus* sp. nov., that has an optimum distribution in the upper levels, a comparison of the average total length and the average temperature at a depth of 200 m. indicates that the maximum average size of the adult female and to a less extent of Stage V is attained in the month of February, while the lowest temperature is found in January. In *Eucalanus attenuatus* (Dana), however, the maximum average length of both Stage V and the adult of both sexes occurs in April, whereas the minimum temperature at 400 to 600 m., where this species has its optimum, occurs in January–February at 400 m. and in January at 600 m.; in this species there is thus a lag of three months. Such a difference would be quite in keeping with Bogorov's conclusion that the temperature in which a species is living affects the size attained by the adult by acting during the process of development, and the suggestion made by Russell that at lower temperatures the rate of development is retarded, maturity being attained later, so that the size to which an individual can grow is increased.

Coker (1933, 1934) has carried out some interesting experiments on the influence of temperature on the size and structure of certain fresh-water Copepoda, and he has shown that "Copepods reared at the lowest temperatures used are invariably so much larger than those reared at the highest temperatures that the difference is quite obvious to the naked eye," and he also showed that in one species, *Cyclops vernalis* Fischer, structural changes could be detected that seem definitely to be correlated with differences in the temperature at which they were reared: he found that "the length of the furca, like the length of the body as a whole, is inversely correlated with the temperature at which the copepods are reared. The correlation for both sexes is plain and unmistakable, the mean length of the furca for each temperature class being the less the higher the temperature of rearing." It is interesting to note that this difference is exactly that met with in varieties or races of two species of the genus *Cyclopina*. Sars (1918–23, p. 12) notes that the variety of *Cyclopina gracilis* Claus, that was recorded by Boeck under the name *C. norvegica* Boeck, possesses caudal rami that are comparatively shorter than in the typical form, and it occurs in shallow creeks and pools left by the tide. Again, the variety of *Cyclopina longicornis* Boeck, described by Brady under the name *C. littoralis* Brady, differs from the typical form in being of smaller size and having the caudal rami less elongated (*vide* Sars, *loc. cit.*, p. 13): here again the variety lives in the littoral zone, whereas the typical form occurs in deeper water. We should thus expect to find in any given species variations in size and possibly also in structure in specimens collected in (1) different geographical regions, and (2) the same region but at different depths or at different seasons. As regards the first the literature abounds with numerous examples. Wolfenden (1906, p. 992) remarks: "It is well known that species, apparently the same, found in the boreal region have, when compared with those of the more southern and warmer areas, often undergone some variation (especially is this the case as to average size), and that some are known to vary greatly within certain defined limits." In a number of species that possess a wide geographical range slight differences of structure have been noted in examples from different localities. Wolfenden (1906) called attention to the differences that exist between specimens of *Paracalanus parvus* (Claus) and *Bradyidius armatus* (van Höffen) from the North Atlantic and the Indian Ocean; Steuer (1917) described a local race of *Acartia* (*Odontacartia*) *pacifica* Steuer from the Aru Islands, and Früchtl (1924) has recorded a number of varieties and forms in other species from the same area, namely:

Centropages furcatus (Dana) var. *carli*,
Acartia (*Odontacartia*) *erythræa* Giesbr. var. *brehmi*,
Oithona brevicornis Giesbr. f. *aruensis*,
O. brevicornis Giesbr. f. *arostrata*,
O. attenuata Farran, var. *latithoracica*,
O. attenuata Farran, var. *latithoracica* f. *trisetosa*,
O. simplex Farran f. *quinquesetosa*,
Corycæus (*Ditrichocorycæus*) *andrewesi*, Farran var. *Rouxi*,
C. (*Ditrichocorycæus*) *asiaticus* F. Dahl var. *mertoni*,

but, as he points out, it is at present impossible to determine to what extent such forms and varieties may be attributed to individual, local or seasonal variation. Gurney (1927*a*) has pointed out that the structural differences between the northern and southern forms of *Paracalanus parvus* (Claus) are exceedingly small and that it is impossible to separate two varieties, but he adds, " On the other hand there is no doubt that there are two races which are, for the time being, separated by the isthmus " (of Suez) ; he also notes that in the Suez Canal area " there are two distinct forms of *Oithona nana*," with slight structural differences, and these he terms typical *Oithona nana* and a southern form. Steuer (1926, p. 56) has recorded from the East Pacific and West Atlantic regions two forms of *Tortanus discaudatus* Thomp. and A. Scott that might be regarded as sub-species. Schmaus and Lehnhofer (1927) have called attention to the Indo-Pacific and Atlantic forms of *Rhincalanus cornutus* (Dana) and have named these f. *typica* and f. *atlantica* respectively. Farran (1929) noted slight differences in the shape of the 5th leg of the female in examples of *Temoropia mayumbæensis* T. Scott, taken in the South-west Pacific region and off the west coast of Ireland, and A. Scott (1909) suggested that the Irish form should be regarded as a distinct species. Again, Farran (1929) has noted slight differences in the number of serrations on the inner margin of the basal segment of the 5th pair of legs in *Calanus finmarchicus* (Gunn.) from northern and southern waters.

As such small differences become more marked, the various forms will come to be regarded as different species ; but for such structural differences to become fixed it would appear to be necessary that there should be at least some degree of isolation. In a few instances this isolation may have been brought about by orographical changes ; thus Stillman Wright (1936) has suggested that two species of *Pseudodiaptomus*, *P. culebrensis* Marsh and *P. marshi* Wright, may have been derived from a common ancestor, and that their separation was effected in Eocene or Miocene times by the upheaval of the Central American Isthmus. In other instances isolation may have been ensured by certain individuals becoming adapted to a different range of physico-chemical characters. Hjort (1911, p. 371) has pointed out that " these (physico-chemical) conditions characterize a given species quite as much as any morphological description, and in fact, for a proper conception of the species both methods of investigation are supplementary." Michael (1911, p. 160) however goes somewhat further and, as regards the Chætognatha, he considers that a species may be defined " as much from the physical environment in which it is normally found as from its morphological characters." It is now generally recognized that one may get so-called biological species within the limits of a morphological species, but for the purpose of this review I prefer to regard such an adaptation as facilitating, and perhaps actually inducing, morphological changes that will eventually result in the evolution of a new species with definite morphological characters. Among littoral-haunting species it is easy to see that local currents may carry individuals from one region to another in which conditions are essentially different, and I have in a previous paper (Sewell, 1940, p. 128 *et seq.*) called attention to certain slight differences of structure that may perhaps be associated with such local conditions.

Steuer (1935) has put forward the view that in circum-equatorial neritic species there is a tendency for these to become dispersed northwards towards the pole, and thus by invading the extensive coast-line of the northern hemisphere to give rise to variations or species ; as an example he cites the genus *Paracartia,* in which we have the following species :

Paracartia grani Sars, from the coasts of Europe.
P. latisetosa Kriczagin, from the Mediterranean Sea, Black Sea and Suez Canal.
P. dubia T. Scott, from the tropical region of West Africa.
P. africana Steuer, from the sub-tropical west African region.

Although it is at present impossible to make any definite statement as to the manner in which these various species have become distributed to their present localities, it is clear that in such coastal regions it is possible for races to be isolated and later to develop into different species, and this will have been particularly easy in the case of species that inhabit brackish-water, if such areas were originally portions of a continuous zone that at some later stage became divided either by the encroachment of pure marine conditions or by orographic changes, as instanced by Willey (1923) in his comparison of the faunas of two stations on the Canadian coast, namely Miramichi estuary and the Basin of Minas : as this author remarks, " while these stations are actually separated by a topographical boundary, the Isthmus of Chignecto, connecting Nova Scotia with New Brunswick, they belong to the same hydrographical system, namely the Acadian sub-basin. The observed distribution of *Pseudodiaptomus* on the east coast of North America is the resultant of former channels of dispersal." In the case of widely distributed oceanic species it is, however, less easy to visualize how a sufficient degree of isolation can have been maintained for a sufficiently long time to permit of such evolution so long as individuals were confined to the open sea and to the same depth, though it is clear that examples might be carried by currents into regions having considerable differences in conditions of temperature and salinity, such as enclosed bays or river estuaries, and numerous instances are to be found in the literature of local varieties of such wide-spread species. Steuer (1923, pp. 7, 40) has drawn attention to the variability of *Acartia clausi* Giesbr. In this species he at first recognized a " giant " race inhabiting the North Atlantic Drift and a " dwarf " race in the Canary Current, but in a later paper (1929) he concludes that these different forms are not geographical races but are correlated with the density of the water in which they are living, and he thus accounts for the presence of the giant race in the Adriatic, where the density of the water is higher even than in the North Atlantic Drift. In the Table below I give the length measurements of the species from different localities :

	Total length.	
Brackish-water :	♀.	♂.
(Gurney)	0·70–0·82	0·71
(Farran)	0·70	. .
(Gurney)	0·83	0·76–0·82

	Total length.	
Marine :	♀.	♂.
New Zealand (Farran)	1·12–1·25	1·05–1·18
East coast of North America (Wilson)	1·15–1·25	1·0–1·1
North Atlantic Drift (Steuer)	1·131–1·265	1·04–1·124
North Sea (Gurney)	1·47	1·31
Norwegian coast (Sars)	1·15	1·0
Bay of Biscay (Farran)	1·2	1·08–1·18
Adriatic (Steuer)	1·222–1·307	1·131–1·209
Canary Current (Steuer)	0·977–1·07	0·99

Associated with these differences in size there are differences in the armature of the posterior margin of the 5th thoracic segment, the number of spinules increasing from 0 in the smaller forms to as many as 5 or 6 in the larger forms. Steuer has given a table showing the number of spines present in specimens from different localities, which I reproduce below, and to which I have added other observations :

Locality.	Number of spinules on the posterior thoracic margin.			
	♀.		♂.	
	Left.	Right.	Left.	Right.
East coast of North America	0			
North Atlantic Drift	1–6	1–5	2–5	2–5
Norwegian coast	4–6			
Adriatic	2–4	3–5	4–6	3–5
Canary Current	0–3	0–4	0	0
	(exceptionally 7)			

Steuer raised the question whether, since these spines seem to be correlated with the size of the specimen and the water of the North Atlantic Drift and of the Canary Current have a common origin in the Gulf Stream, these differences will disappear in specimens from the western area of the Atlantic, but, as he remarked, at the time of writing we then knew nothing regarding the occurrence of this species in the western region. Since then Wilson (1932) has recorded that in specimens taken in the Woods Hole region of the American coast these spinules are absent. Variation on parallel lines has been found to occur in another species of the same genus : in 1913 I noted that specimens of *Acartia centrura* Giesbr. taken in the brackish water of the Chilka Lake, India, were smaller in size than those taken in the open sea, and that the spines on the posterior margin of the 5th thoracic segment and the distal border of the abdominal segments are smaller than usual in this species. Gurney (1931, p. 224) considers that a definite brackish-water or estuarine form of *Acartia clausi* can be recognized ; and a distinct variety has been described as var. *gaboonensis* T. Scott, from the coastal region of the Cameroon Bight in the Gulf of Guinea, and a sub-species, *Acartia clausi hudsonica* Pinney, from Hudson Bay and the mouth of the St. Lawrence River in America. One of the commonest of deep-sea species, *Eucalanus elongatus* Dana, also appears to undergo structural variations as we trace it eastwards from the Atlantic Ocean, through the Indian Ocean to the Pacific. The Atlantic form was recorded by Claus under the name *hyalinus*, and Giesbrecht (1895) described a variety, *inermis*, from the Pacific. Johnson (1938) has suggested that this Pacific form should be regarded as a distinct species, but examples taken in the Indian Ocean are intermediate between the forms *hyalinus* and *inermis*.

At first sight it would seem to be unlikely that there can be in any given level of the ocean, in which the changes in oxygen concentration, pH concentration, salinity and temperature are relatively small, such differences as could explain the evolution of local races: nor is it easy to see how any variety that may occur can be sufficiently isolated to permit of the formation of particular races or sub-species, unless the vertical migration is sufficiently great to carry examples from one current system to another either in the same or in a different ocean. That slight changes in structure, associated with changes in size, are not confined to surface-living forms, but may also occur in deep-water forms, seems to be indicated by the presence in the Indian Ocean of a variety of the North Atlantic species, *Candacia norvegica* Boeck, namely var. *tropica* Sewell, that was described by me (1932) from the Laccadive Sea. Similarly, the species *Euchirella bitumuda* With is a North Atlantic species, and its place is taken in the Indo-pacific region by *E. galeata* Giesbrecht. Farran (1926, p. 253) considers these two forms to be distinct species, but the differences are so slight that they may equally well be regarded as geographical races of a single widespread species, comparable to the two forms, Indo-Pacific and Atlantic, of *Rhincalanus cornutus* (Dana). In the genus *Pleuromamma* Steuer (1932) has described a number of different forms, which he has attempted in some degree to correlate with definite water masses: unfortunately in many instances he refers to the locality from which examples were obtained by the name of the surface current, although the depth at which the specimens were taken shows that they were too deep for this water and must have been living in a different water mass. In *Pleuromamma gracilis* (Claus) he recognizes three forms: f. *minima*, as its name implies the smallest, occurs in the upper levels between 150 and 400 m. depth in the tropical and sub-tropical regions of the North Atlantic; it has been taken in the Canary Current at 150 m., in the Benguela Current at 350–500 m., in the Gulf of Guinea at 400 m., and in the South Equatorial Current at 200 m.; in the Irminger Current it occurs at 400 m., in the Labrador Current at 700 m., and in the Sargasso Sea between depths of 450 and 700 m. It is now known that the warm water of the Irminger Current sinks downwards off the west coast of Greenland, and turning first west and then south forms the intermediate mass of water in the Labrador Sea between 500 and 2000 m. In the region of the Sargasso Sea the surface water is sinking down to form the North Atlantic Intermediate water, and it thus appears probable that this form, *minima*, may be carried downwards in this water mass and so enter the North Atlantic Intermediate Current.

At a somewhat deeper level in the Atlantic the f. *piseki* is to be found; this form has been taken in the Benguela Current at 350–500 m. depth and in the Labrador Current at a depth of 750 m.; in the Sargasso Sea it has been taken between 500 and 850 m., and hence it too is an inhabitant of the North Atlantic Intermediate water, but at a slightly deeper level than f. *minima*. Finally f. *maxima* is found in the water of the West Wind Drift at 500 m.

Similarly, *Pleuromamma abdominalis* (Lubb.) possesses several distinct forms that are, in all probability, associated with distinct water masses: thus f. *typica* occurs mainly in the upper stratum; f. *edentata* occurs in the tropical region of the Indian Ocean at a depth of 520–1500 m., which suggests that it is an inhabitant of the Indian Intermediate Current, and below the Benguela Current in the South Atlantic Ocean at 1000 m. and so in the Sub-polar Intermediate Current: Steuer's conclusion that its presence in this latter area is due to the Agulhas Current seems to be inadmissible. A third form, f. *abyssalis*, occurs in the West Wind Drift between 900 and 1500 m. depth, below the Benguela Current at 600–1000 m. depth and in the tropical region of the Indian Ocean at 520 m., so that it, too, appears to be an inhabitant of the South Polar Intermediate water. Below the Indian Equatorial Current at a depth of 800 m. we find a special sub-form, *thermophila*, which seems to be an inhabitant of the Indian intermediate water, and in the tropical belt of the Pacific Ocean the same sub-form occurs between 1000 and 4000 m., where it seems to be living in the Pacific intermediate water.

Provided the degree of isolation is sufficient and is continued for a sufficiently long time, such changes in size and structure may give rise to different species, and we may suppose that the ancestral forms of the genus *Rhincalanus* became adapted to life at different levels and in different current systems, and that, as a result of this isolation, three species were evolved, the smallest, *R. cornutus* (Dana), inhabiting the surface layer, the middle one, *R. nasutus* Giesbr., inhabiting the intermediate depths, and finally, the largest, *R. gigas* Brady, occurring only in the deepest levels.

In a number of species examples that have been taken at the same depth and in the same area appear to fall into groups according to their length measurements: in most of such cases two groups have been recorded, but in a few there have been three. In the majority of such instances there seems to be little or no difference in actual structure. In previous papers (Sewell, 1912, 1929, 1932 and 1940) I gave details of such groups in the following species from Indian waters and elsewhere:

Nannocalanus minor (Claus)
Undinula vulgaris (Dana).
Paracalanus aculeatus Giesbr.
Clausocalanus arcuicornis (Dana).
Lophothrix frontalis Giesbr.
Pleuromamma abdominalis (Lubb.).
Lucicutia flavicornis (Claus).
Oithona plumifera Baird.
O. setigera (Dana).
Euryte longicauda Philippi.
Harpacticus littoralis Sars.
Porcellidium fimbriatum Claus.
Eudactylopus opima (Brian).
Amphiascus calcarifer Sewell.
A. debilis Giesbr.
Teissierella knoxi Thomp. and A. Scott.
T. propinquua (T. Scott).
Ceyloniella armata (Claus).
Metis jusseaumei Richard.

Similar groups have been recorded in other species, some of which are surface-living forms, while others are from deeper levels:

Species.		Average length in mm.	
		f. major.	f. minor.
Calocalanus styliremis Giesbr.	♀	0·92–0·95	0·65–0·74
Pseudocalanus elongatus Boeck	♀	1·9	1·63
	♂	1·44	1·36
Spinocalanus abyssalis Giesbr.	♀	1·45–1·60	0·95–1·08 (f. *pygmæa*)
(*vide* Farran, 1926, p. 242)	♂	1·80–2·06	1·18–1·20
Gætanus kruppi Giesbr.	♀	5·71	4·8–5·1
Scaphocalanus magnus (T. Scott)	♀	4·97	3·55
Heterorhabdus austrinus Giesbr.	♀	3·42–3·85	2·97–3·18
(*vide* Farran, 1929, p. 265)	♂	3·48–3·60	2·84–2·98

Augaptilus longicaudatus (Claus)	♀	3·5–4·3	4·5–5·9
Oithona nana Giesbr. (*vide* Gurney, 1927, p. 159)		0·62–0·69	0·53–0·55
Oncæa media Giesbr.	♀	0·74–0·82	0·58–0·65
	♂	0·63–0·68	0·54–0·62
O. venusta Philippi (*vide* Farran, 1929, p. 284)	♀	1·08–1·16	0·92–1·07 (var. *vanella*)
(present collection)	♀	1·10–1·26	0·80–0·95

Farran (1936) has described three such groups in *Oncæa conifera* Giesbr.; these differ from one another in small anatomical details as well as in size, and he considers that form b is entitled to rank as a variety, which he terms var. *furcula*. The sizes of these three groups are as follows:

		Form a.	Form b.	Form c.
Oncæa conifera	♀	1·15–1·20	1·08–1·14	0·96–1·02 mm

The occurrence of such size groups at the same time and in the same locality is not confined to marine copepods, but has also been recorded in species that inhabit brackish- or fresh-water. T. Scott (1905*a*, p. 49) has recorded the presence of two such groups in the species *Eurytemora herdmani* Thomp. and A. Scott in the St. Lawrence River:

	Small form.	Large form.
♀	1·12 mm.	1·52 mm.
♂	1·14 ,,	1·61 ,,

and Gurney (1931) has recorded the same phenomenon in two species of the genus *Diaptomus* from fresh water:

		Small form.	Large form.
Diaptomus gracilis Sars	♀	0·99–1·2	1·4
	♂	0·98–1·17	1·26–1·35
Diaptomus wierzejskii Richard	♀	1·590	2·150
	♂	1·338	1·635

Different authors have attributed these groups to different causes: thus Störmer (1929), who found them off the west coast of Greenland, attributes them to a mixture of water of different origins, each having its own race of copepod, while Ottestad (1932), who recorded them from the Antarctic, attributes them to different broods, one having survived from the previous year. Marshall (1933), who found similar groups in *Calanus finmarchicus* (Gunn.) in the Clyde area, in water that appeared to be homogeneous, is inclined to think that they may have been different broods, a smaller surface-living brood and a larger deeper dwelling one, following the suggestion put forward by Russell (1928) that the small summer brood lives nearer the surface than the larger winter brood. Gurney (1931) attributes the occurrence of the two groups in *Diaptomus* to an extra moult from Stage VI to Stage VII, and he states that in the case of *Diaptomus laticeps* Sars " the range of size in Loch Hundland is so great that it seems necessary to suppose that in some cases there is a moult in the adult to a ' high form ' or Stage VII, which is not distinguished by structural change."

Coker (1934) has discussed the possible causes of the production of such groups, and he divides these into—

(1) The production of two forms at different stages in the life-history of the same individual. This he regards as very improbable among the Copepoda. I have however, in contrast, put this view forward as the explanation in several species that I have investigated (*vide* Sewell, 1914, 1929, 1932 and 1940), and Gurney (1931) has indicated that it is the explanation of the two forms of *Diaptomus wierzejskii* Rich. and *D. laticeps* Sars.

(2) The production in any given area of seasonal, e.g. winter and summer, forms. This phenomenon is termed " cyclomorphosis."

(3) The production of two or more forms by difference in the development of individuals from the same batch of ova. This Coker terms " true Dimorphism."

(4) The development of different races or varieties, which may occur—
  (a) simultaneously in different places ;
  (b) simultaneously in the same place ;
  (c) successively in the same or different places, one or both being dominant for part of the year.

In certain well-known species, such as *Calanus finmarchicus* (Gunn.) and *C. hyperboreus* Kröyer, size groups are known to occur, and have been attributed to differences, either seasonal or geographical, in the general hydrographic conditions : as regards seasonal changes it has been shown that in the North Atlantic *Calanus finmarchicus* (Gunn.) exhibits three generations a year, each generation giving rise to another that differs somewhat, and such a phenomenon falls into Coker's category (2), the phenomenon known as " cyclomorphosis." In the species noted above, however, the two forms have been taken in the same locality and at the same time, and therefore, presumably, must fall into Coker's category (3) or (4b). That the phenomenon is not a local one is indicated by the fact that in certain species this production of two size groups has been noted in different oceans. It is now recognized that there is a possibility that so-called " physiological " races may be developed within the limits of a single " morphological " species, as was suggested by Appellöf (1912), but such a development is correlated with different conditions in different habitats, and thus is comparable to the formation of geographical races. Runnstrom (1928) has, however, further suggested that these " physiological " races may have developed a different breeding season ; they could thus be taken in the same locality in the adult stage at different times of the year, or, if their length of life were sufficiently long and the two breeding seasons not too far apart, they might even overlap, and so be taken at the same time of the year and in the same locality in two different phases of adult life, viz. pre-breeding and post-breeding. Such an explanation, however, is improbable, since in the case of species that inhabit the warm surface water of the tropical and sub-tropical regions, the average span of life is almost certainly much shorter than in the colder waters of the temperate and boreal regions, where, as in the case of *Calanus finmarchicus* (Gunn.), there are only two or three generations in a year, and, furthermore, the temperature differences are relatively so small that they are, as noted above (*vide supra*, p. 369), insufficient to cause so clearly marked a difference in size. It seems to me that one is thus thrown back on the explanation that these two size groups in certain species may and probably do represent either successive stages in the life-history of a single individual, as in Coker's category (1), or else are the result of differences in the development of individuals from the same brood, as in Coker's category (3), but, if the latter were the true explanation, one would certainly get similar size groups in the immature stages, and this does not appear to be the case, and in those instances in which two groups of the adult have been obtained, the size difference between the groups corresponds closely to what one would expect if the large form were obtained by an additional moult from the adult to the post-adult stage or Stage VI to Stage VII.

In yet other instances it is found that in different regions this difference in size is accompanied by small differences of structure and the two forms have been described as different species. Examples of this are :

Species.	Total length in mm.	
	♀.	♂.
Heterostylites longicornis (Claus)	2·50–3·50	..
H. major (Dahl)	4·40–5·00	..
Valdiviella ignota Sewell	6·5	..
V. insignis Farran	8·7	..
Chiridius nasutus	2·67–2·88	..
C. armatus Boeck	3·6–4·43	..
Heterorhabdus abyssalis (Giesbr.)	2·2–2·6	2·0–2·6
H. norvegicus (Boeck)	2·8–3·4	2·8–3·1
Cornucalanus chelifer (Thomp.)	6·0	..
C. magnus Wolfend.	7·8–8·0	6·0

and to these may perhaps be added :

Species.	♀.	♂.
Scolecithricella longicornis (T. Scott)	1·25	..
S. ctenopus (Giesbr.)	1·47	..
Euryte minor T. Scott	1·00	..
E. longicauda Philippi	1·30	..
Isochæta ovalis Giesbr.	1·34–1·50	1·22–1·32
Lucicutia frigida Wolfend.	1·50–1·60	..
L. flavicornis Claus	1·47–1·58	1·44–1·56
L. gemina Farran (*vide* Farran, 1926)	1·75–1·86	1·63–1·72
P. scotti Sewell	1·511	1·419
Pontellopsis macronyx A. Scott	1·733	..

Vervoort (1946) has given a list of several pairs of species which are probably growth classes of the same species, namely :

Pontellopsis herdmani Thompson and A. Scott and *P. macronyx* A. Scott.
Heterorhabdus abyssalis (Giesbr.) and *H. norvegicus* (Boeck).
Oithona challengeri Brady and *O. plumifera* Baird.
Gætanus minor Farran and *G. minimus* Wolfenden.
Valdiviella insignis Farran and *V. ignota* Sewell.

It is possible that *Pontellopsis herdmani* Thompson and A. Scott, *P. macronyx* A. Scott and *P. scotti* Sewell, are all members of the same species.

In the genus *Pseudocalanus*, three so-called species, differing in size, have been recognized :

	♀	♂
Pseudocalanus elongatus Boeck	1·40 (average)	. .
P. gracilis Sars	1·65	. .
P. major Sars	2·40	. .

With (1915, p. 66) suggests that some of the differences between these forms are congenital, while others may be attributable to differences of habitat.

In the genus *Clausocalanus* the matter appears to be still more complicated, for Farran (1926, p. 236) has recorded the occurrence of as many as four groups, to two of which he has given specific names :

	♀	♂
Clausocalanus paululus Farran	0·75–0·82	. .
C. pergeus Farran	0·90–1·05	. .
C. arcuicornis Claus f. *minor*	1·20–1·40	. .
C. arcuicornis Claus f. *major*	1·40–1·60	. .

In certain of the above instances the production of the two forms or " species " can be correlated with differences of habitat. Thus *Heterorhabdus norvegicus* (Boeck) is an arctic and North Atlantic form, inhabiting cold water, and has a distribution that extends southwards as far as lat. 29° N., whereas *H. abyssalis* Giesbr. appears to be an inhabitant of the South Polar intermediate current, its distribution extending from the region of the Cape of Good Hope northwards into the Atlantic Ocean as far as the west coast of Ireland and the Bay of Biscay, where Farran (1926) found that it showed a maximum concentration at a depth of 186–366 m. (100–200 fms.), as opposed to *H. norvegicus* (Boeck), that exhibited a maximum at 366–549 m. (200–300 fms.). As one would expect of an inhabitant of the South Polar intermediate current, *H. abyssalis* (Giesbr.) also extends northwards into the Indian Ocean as far as the Arabian Sea and the Gulf of Oman, where it was taken at a depth of some 400–650 m. The presence of two forms of the same species in different oceans, for instance, the one in the Atlantic and the other in the Indo-Pacific region, has been adduced as evidence in favour of the view that the Plankton of these two areas presents more or less specific differences. The data that Schmaus and Lehnhofer (1927) have given for the distribution of the species *Rhincalanus cornutus* (Dana) clearly indicates that individuals of the Indo-pacific form, f. *typica*, can at the present time be carried westward round the Cape of Good Hope into the region of the Benguela current and the Gulf of Guinea, and presumably when this transfer first took place, whether by this route or by any other such as the Tethys Sea in the Tertiary epoch, the change in conditions which the individuals experienced was accompanied by a change of structure in their offspring that gave rise to the f. *atlantica*, and it was this new form that was able to populate the Atlantic Ocean. If this be so, then it would appear that subsequent invaders of the f. *typica* have either been unable to establish themselves in face of the competition with the new form, f. *atlantica*, and so die out, or else their progeny has undergone exactly the same mutation. In the case of those closely related forms of the same species, such as we find in *Pleuromamma gracilis* (Claus) and *P. abdominalis* (Lubb.), that are to be found at different levels or in different parts of the same circulatory system in any one ocean, we are faced with a different problem. Between such water masses as the Sub-polar and North Atlantic intermediate currents there lies a zone of admixture ; thus examples of *P. gracilis* f. *maxima*, which apparently inhabits the West Wind Drift and thus can be carried northwards towards the tropics, may be transported across the boundary zone into the North Atlantic intermediate water, which appears to be the habitat of f. *piseki* (Farran), so that either f. *maxima* must die out or else its progeny must undergo transformation into f. *piseki*. Similarly, the various so-called " races " of *Acartia clausi* Giesbr., which are to be found in various parts of the North Atlantic circulatory system, cannot be regarded as definite biological entities ; as we trace the North Atlantic Drift eastwards some of the water may be swept to the north-east and so reach the North Sea, while another mass may be swept to the south and so reach the Mediterranean Sea, and in all three regions we find the so-called " giant " race, but there is no break between the southerly branch of the North Atlantic Drift and the Canary Current, in which we find the so-called " dwarf " race, and it follows that specimens of the giant race that are carried southwards into the Canary Current will after one or more generations, depending on the length of time taken to transport examples from one region to the other, give rise to examples of the dwarf form, that will themselves be swept westward in the North Equatorial Current to the Carribean Sea and the east coast of North America, where they are to be found in the region of the Gulf Stream, and then continuing onwards into the North Atlantic Drift will again give rise to the " giant " form ; and it seems probable that these two different forms are correlated with differences in the salinity and temperature of the water-mass in which they are living. If this be so, then it seems clear that such forms are examples of the phenomenon of " cyclomorphosis," similar to that found in *Calanus finmarchicus* (Gunn.), which possesses definite seasonal forms dependent on the temperature of the surface water.

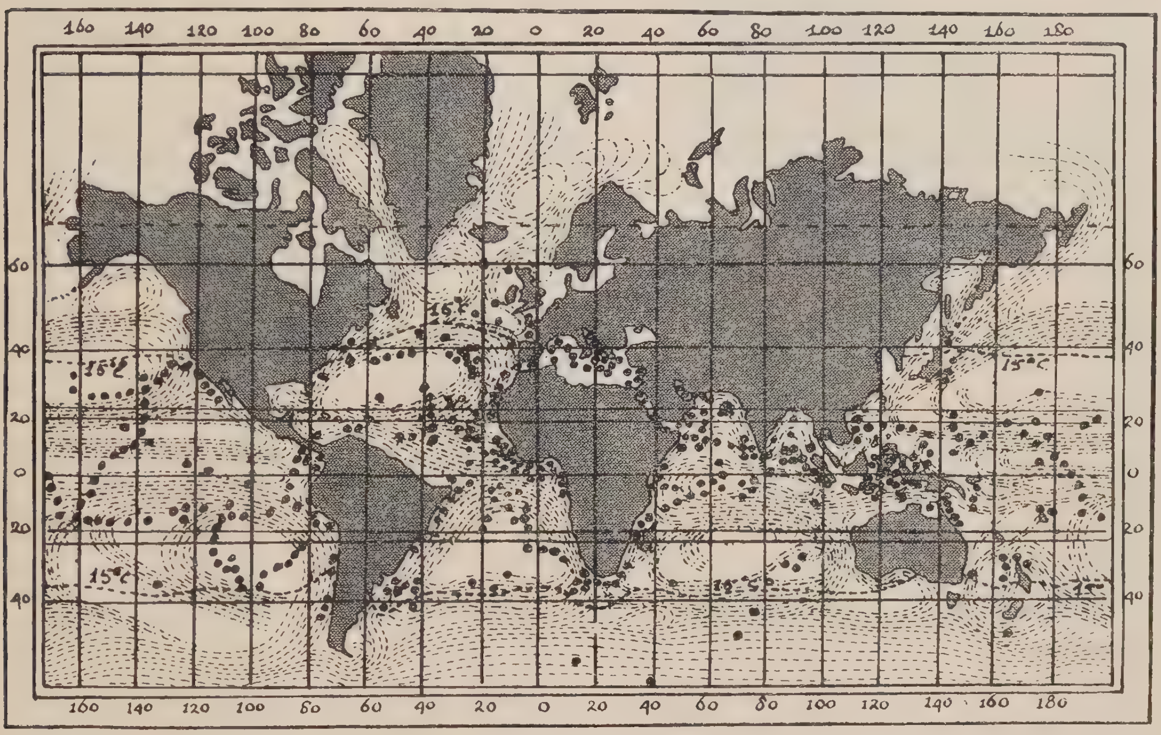
It seems to me that the evidence that we have been studying indicates that the Copepods are extremely plastic, and that as we trace the distribution of any given species along the current system in which it is living, the parent form, when it reaches an area of different physical and chemical composition, may give rise to offspring that differ from the parent in size and even in structure, so that, perhaps not infrequently, the two forms have been described as different species. The presence of two such forms in different oceans must not therefore be taken to be evidence in favour of the specificity of the fauna of the two regions but rather as evidence of continuity, either at the present time or in the past, of distribution.

GEOGRAPHICAL DISTRIBUTION.

Although our knowledge of the distribution of many of the species is still incomplete, and it is probable that future researches, especially in the Pacific Ocean, will reveal the existence in that area of species that are yet unknown and of others that are at present known only from more western regions, it seems to me that we now know enough to justify one in attempting to trace the broad lines along which distribution has been carried out, and the degree to which this is dependent on the movement of the great water-masses of the oceans. It has been shown (*vide supra*, p. 327) that in the planktonic species there are two main groups that can be separated by the depth of their habitat, though a few are capable of surviving such wide changes of conditions that they may be taken in most areas and most depths : these two groups are (1) those that inhabit the upper levels and are for the most part to be found in the upper 400–500 m., especially in the tropical and temperate regions, that is to say in that part of the ocean that Defant terms the "Troposphere," and (2) those that are usually to be found in greater depths, except in the subpolar and polar regions, where they may be taken at or near the surface, and that thus correspond to the mass of water that Defant terms the "Stratosphere." In order therefore to trace the distribution of these planktonic animals we must consider each group separately.

THE DISTRIBUTION OF THE EPI-PLANKTONIC SPECIES.

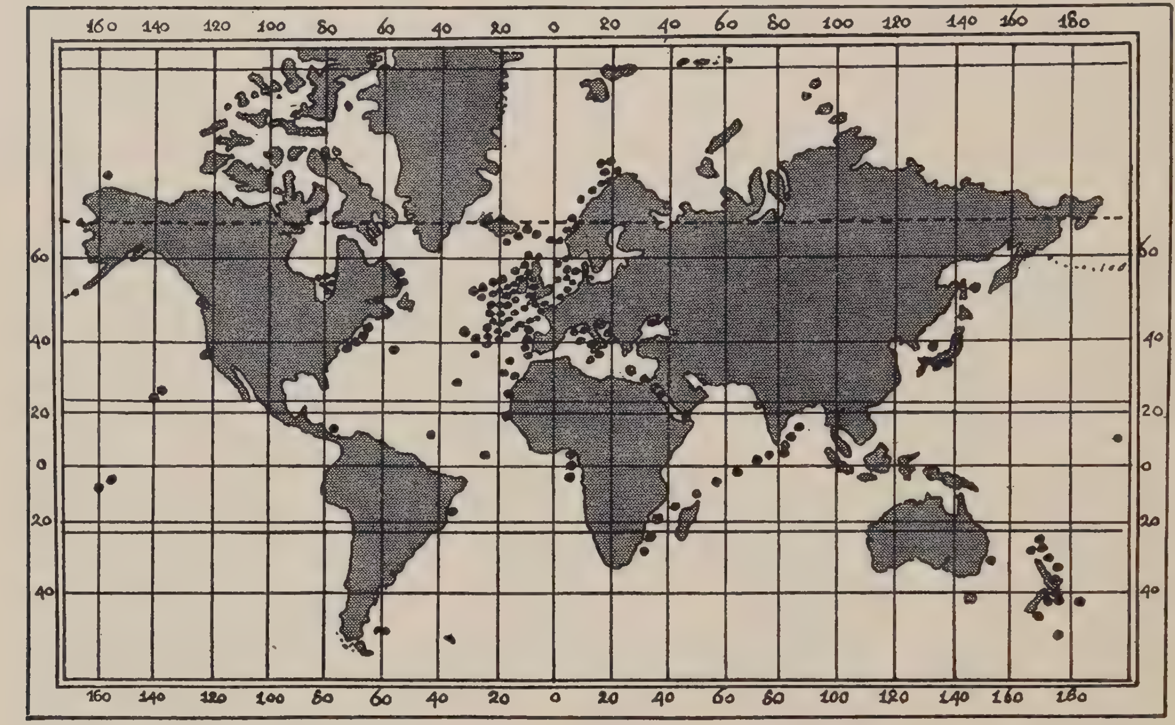
It is now well known that many of the epi-planktonic genera and species are to be found widely distributed throughout all the three great oceans. Lehnhofer (1926, p. 147, Text-fig. 20) has given a map, showing the distribution of the genus *Copilia* Dana, in the Indian and Atlantic Oceans, and this clearly indicates how close is the agreement between the distribution and the general trend of the surface currents in this area ; and the same agreement can be traced in other genera. The same author (Lehnhofer, 1929), regarding the distribution of the genus *Sapphirina* J. V. Thompson, has stated that this is to be found for the most part in the circum-tropical belt, though, in comparison with the genus *Copilia*, the boundaries of their occurrence reach further towards the Arctic and Antarctic regions. In the accompanying map (Text-fig. 83) I have given the known present-day distribution of this genus, and from it it is clear that for the most part the range falls within the limits of the warm-water circulation of the tropical and temperate regions, though in a few instances species and individuals have been taken in higher latitudes in the Antarctic :



TEXT-FIG. 83.—Sketch Chart showing the distribution of the genus *Sapphirina*, and the position of the 15° C. isotherm of the annual mean temperature of the surface-water.

the close connection that exists between this genus and the pelagic Tunicata may possibly provide an explanation of this wider migration, but since the pelagic Tunicata are themselves dependent on the currents for their distribution, the relationship between the surface currents and the presence of the Sapphirinidæ is not affected.

In attempting to trace the dispersal of these planktonic forms it is essential that we should take a wide view of what constitutes a species. Furthermore, any explanation of such dispersal should also serve to explain the distribution of sub-species or closely related species, since, if these have evolved the one from the other or both from a common ancestor, they must at the commencement of the process of evolution have occupied the same or contiguous geographical areas, their subsequent separation being brought about either by being carried into different regions by the then existing currents, or by becoming separated at some later period by topographical changes. One must equally guard against the fatally easy process of rejecting all data that do not fit in with one's preconceived notions: for instance, when discussing the distribution of *Acartia clausi* Giesbr. Steuer (1923, p. 51), who regards this as a strictly Atlantic form, expresses astonishment that Thompson and A. Scott, when in 1903 they reported the presence of this species on the Ceylon Pearl Banks, were not struck with surprise, since according to Steuer this was the first report of its occurrence in the Indo-Pacific region. Steuer, however, has overlooked the fact that three years earlier, Thompson (1900) had recorded its presence from no fewer than 20 stations in the Indian Ocean, Arabian Sea and Red Sea; and it hardly seems likely that this author, who had done so much work in the Atlantic Ocean, was not correct in his diagnosis. *Acartia clausi* (*vide* Text-fig. 84) has now been recorded from the North-



Text-fig. 84.—Sketch Chart showing the distribution of *Acartia clausi* Giesbr. (*sensu lato*).

Pacific Ocean (Wilson), the west coast of North America (Esterly), the Alaskan coastal region (Willey), the south-west Pacific Ocean around New Zealand (Farran), the coast of New South Wales (Dakin and Colefax), the Indian Ocean, Ceylon Pearl Banks, Arabian Sea and Red Sea (Thompson, Thompson and A. Scott), the Gulf of Guinea and the Guinea Current (T. Scott, Rose), the tropical Atlantic (Farran), throughout the eastern North Atlantic region (Giesbrecht, Sars, Rose, Farran), throughout the Mediterranean Sea (Claus, Thompson, Thompson and A. Scott, Pesta, Car), and the Black Sea (Karawajew), off the coast of France (Canu), round the British Isles and in the English Channel (Thompson, Norman and T. Scott, Farran, Pearson), in the North Sea (Gurney), Kiel Bay (Canu, Kunz), off the coast of Norway (Sars), in the Arctic Ocean (Mrazek), off Labrador (Jespersen), in Hudson Bay (Willey), and off the east coast of North America (Williams, Wilson, Bigelow, Fish). Two other so-called species that are very closely related to, if not actually identical with, *Acartia clausi*, namely *A. simplex* Sars and *A. ensifera* Brady, have been recorded from the south-west Pacific region; and Farran (1929) regards the latter as a synonym of *A. clausi*. Certainly all three forms are very closely related, and it seems to be merely a matter of individual opinion whether they are regarded as forms of a single widespread species, which exhibits slight local variations, as one might expect, in widely separate localities such as the variety, var. *gaboonensis* T. Scott, from the Guinea Current and the Gulf of Guinea, and the sub-species *A. clausi hudsonica* Pinney from Hudson Bay, or, alternatively, as three very closely related species that have evolved in different localities from a single widely-dispersed ancestor: personally I prefer the former view and, judged from this standpoint, it seems clear that far from being an Atlantic form, *Acartia clausi* (*sensu lato*) is a species of world-wide distribution.

In order to be able to form a general idea regarding the mode and direction of distribution of such planktonic forms it is essential that we should reach a conclusion regarding their source of origin. Steuer (1933, p. 275) claims that "Die Südhalbkugel ist der Ausbildung von ozeanischen Formen, die küstenreiche Nordhalbkugel der Entwicklung neritischer Formen günstig." That the majority of the so-called oceanic species are found to be living in the southern hemisphere is due solely to the geographical distribution of land and sea, the southern hemisphere being almost entirely oceanic. The assumption that these oceanic species originated in the southern hemisphere is entirely unwarranted. Similarly, so-called "neritic" species may have originated along any stretch of coast, especially in regions where there is a change in local conditions. In tropical regions, where large rivers open into the ocean, a number of species, that may be called neritic, appear to have had their origin, but many of these exhibit a marked tendency to invade brackish water and even to penetrate upstream, so that they ultimately become inhabitants of fresh water, rather than pass seawards and take up their habitat in the open ocean. One region that appears to have been extremely prolific in the production of new species of this type is the Malay Archipelago and the neighbouring region of the Bay of Bengal, others are the east coast of South America and the south and south-east coast of Australia and New Zealand. Steuer (1933) has also pointed out that a number of Atlantic genera and sub-genera are represented in the Indo-Pacific region, and that in such instances the Indo-Pacific species are found to be the more primitive. Burckhardt (1913), several years earlier, pointed out that in the genus *Oithona* a large number of species are known from the Atlantic Ocean, but that these all belong to only two of the various groups into which the genus can be divided, whereas from the Pacific Ocean we know of many species among which are representatives of all these various groups; and he therefore concludes that the genus has radiated from the Pacific Ocean. During Tertiary times, when there was a direct connection by means of the Tethys Sea between the Pacific and Atlantic Oceans and another one across Central America between the Atlantic and Pacific, warm-water epi-planktonic species might have arisen in any part of the system and have rapidly become cosmopolitan, but with the closure of the Tethys and the upheaval of Central America such species will have found it difficult to pass from the Indo-Pacific area to the Atlantic and impossible to get from the Atlantic to the Pacific. As I have previously pointed out (Sewell, 1929, p. 4), " such differences as do occur in the copepodid fauna of the two regions (Atlantic and Pacific) are to be attributed to the occurrence in the Atlantic Ocean of an indigenous fauna that has been evolved in that region and, owing to the total absence of any connecting passages between the tropical and temperate regions of this ocean and the Pacific or Indian Oceans, for as a possible route for the dispersal of planktonic marine organisms the Panama Canal can be ignored, these indigenous forms are completely unable to extend their habitat." It thus seems to me that such evidence as we now possess points to the Pacific Ocean as being the original place of origin of the warm-water epi-planktonic Copepoda.

Thanks to the work of Dana (1847–49), Giesbrecht (1892), Esterly (1905, 1924), Campbell (1929), Johnson (1938) and Wilson (1942), we now have records of 184 epi-planktonic Copepoda from the East Pacific region, namely:

Calanus cristatus Kröyer.
C. finmarchicus (Gunn.).
C. hyperboreus Kröyer.
? *C. propinquus* Brady.
C. tonsus Brady.
Nannocalanus minor (Claus).
Canthocalanus pauper (Giesbr.).
Undinula caroli (Giesbr.).
U. darwini (Lubb.).
U. vulgaris (Dana).
Eucalanus bungii bungii Giesbr.
E. bungii californicus Johnson.
E. crassus Giesbr.
E. monachus Giesbr.
E. mucronatus Giesbr.
E. pileatus Giesbr.
E. subcrassus Giesbr.
E. subtenuis Giesbr.
Rhincalanus cornutus f. *typica* Dana.
Mecynocera clausi Thompson.
Paracalanus aculeatus Giesbr.
P. parvus (Claus).
Acrocalanus gibber Giesbr.
A. gracilis Giesbr.
A. longicornis Giesbr.

A. monachus Giesbr.
Calocalanus pavo (Dana).
C. plumulosus (Claus).
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
Drepanopus forcipatus Giesbr.
Pseudocalanus minutus Kröyer (= *elongatus* (Boeck)).
Microcalanus pusillus Sars (? = *pygmæus* Sars).
M. pygmæus Sars.
Ctenocalanus vanus Giesbr.
Euchæta acuta Giesbr.
E. flava Giesbr.
E. grandiremis Giesbr.
E. japonica Marukawa.
E. longicornis Giesbr.
E. marina (Prestand.).
E. media Giesbr.
E. philippi Brady.
Scolecithrix danæ (Lubb.).
Scolecithricella bradyi (Giesbr.).
S. minor (Brady).
S. porrecta (Giesbr.).
Centropages brachiatus (Dana).
C. bradyi Wheeler (= *violaceus* Brady, pars).
C. calaninus (Dana).
C. elegans Giesbr.
C. elongatus Giesbr.
C. furcatus (Dana).
C. gracilis (Dana).
C. mcmurrichi Willey.
Pseudodiaptomus (*Pseudodiaptalloas*) *euryhyalinus* Johnson.
Eurytemora hirundoides (Nordquist).
E. johanseni Willey.
E. transversalis Campbell.
Temora discaudata Giesbr.
T. stylifera (Dana).
Lucicutia flavicornis (Claus).
Candacia æthiopica Dana.
C. bipinnata Giesbr.
C. bispinosa Claus.
C. catula Giesbr.
C. columbiæ Campbell.
C. curta Dana.
C. pachydactyla Dana.
C. pectinata Brady (= *armata* Boeck).

C. simplex Giesbr.
C. truncata Dana.
Labidocera acuta (Dana).
L. acutifrons (Dana).
L. detruncata (Dana).
L. jollæ Esterly.
L. lubbocki Giesbr.
L. trispinosa Esterly.
Paralabidocera amphitrites McMurrich.
Pontella agassizi Giesbr.
P. atlantica (M. E.).
P. danæ Giesbr.
P. fera Dana.
P. lobiancoi (Canu).
P. princeps Dana.
P. securifer Brady.
P. tenuiremis Giesbr.
Anomalocera patersoni Templ.
Pontellopsis lubbocki (Giesbr.).
P. occidentalis Esterly.
P. regalis (Dana).
Pontellina plumata Dana.
Acartia clausi Giesbr.
A. danæ Giesbr.
A. denticornis Brady.
A. laxa Dana.
A. lilljeborgi Giesbr.
A. longiremis (Lillj.).
A. negligens Dana.
A. tonsa Dana.
Tortanus discaudatus (Thomp. and A. Scott).
T. forcipatus (Giesbr.).
Oithona atlantica Farran (= *spinirostris* Claus).
O. attenuata Farran.
O. brevicornis Giesbr.
O. hebes Giesbr.
O. linearis Giesbr.
O. nana Giesbr.
O. plumifera Baird.
O. setigera (Dana).
O. similis Claus (= *helgolandica* Sars).
Oncæa anglica Brady.
O. borealis Sars.
O. conifera Giesbr.
O. curta Sars.
O. dentipes Giesbr.

O. media Giesbr.
O. mediterranea Claus.
O. minuta Giesbr.
O. notopus Giesbr.
O. ornata Giesbr.
O. similis Sars.
O. subtilis Giesbr.
O. tenella Sars.
O. tenuimana Giesbr.
O. venusta Philippi.
Conea rapax Giesbr.
Lubbockia aculeata Giesbr.
L. squillimana Claus.
Corycæus (*Corycæus*) *clausi* F. Dahl.
C. (*C.*) *crassiusculus* Dana.
C. (*C.*) *speciosus* Dana.
C. (*C.*) *vitreus* Dana.
C. (*Monocorycæus*) *robustus* Giesbr.
C. (*Agetes*) *flaccus* Giesbr.
C. (*A.*) *limbatus* Brady.
C. (*A.*) *typicus* Kröyer.
C. (*Urocorycæus*) *furcifer* Claus.
C. (*U.*) *lautus* Dana.
C. (*U.*) *longistylis* Dana.
C. (*Ditrichocorycæus*) *africanus* F. Dahl.
? *C.* (*D.*) *anglicus* Lubb.
C. (*D.*) *andrewsi* Farran.
C. (*D.*) *tenuis* Giesbr.
C. (*Onychocorycæus*) *agilis* Dana (= *gracillicaudatus* Giesbr.).
C. (*O.*) *catus* F. Dahl.
C. (*O.*) *giesbrechti* F. Dahl.
C. (*O.*) *ovalis* Claus.
C. (*O.*) *obtusus* Dana.
C. (*O.*) *pumilus* M. Dahl.
C. (*O.*) *pacificus* F. Dahl.
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *concinnus* Dana.
C. (*C.*) *curtus* Farran.
C. (*C.*) *gibbulus* Giesbr.
? *C.* (*C.*) *gracilis* Dana.
C. (*C.*) *rostratus* Claus.
Sapphirina angusta Dana.
S. auronitens Claus—*sinuicauda* Brady.
S. bicuspidata Giesbr.
S. iris Dana (= *longifurca* A. Scott).
S. metallina Dana.

S. nigromaculata Claus.
S. opalina Dana—*darwini* Haeckel.
S. ovatolanceolata Dana—*gemma* Dana.
S. scarlata Giesbr.
S. stellata Giesbr.
Copilia lata Giesbr.
C. mediterranea (Claus) (= *denticulata* Claus).
C. mirabilis Dana.
C. quadrata Dana.
C. vitrea (Haeckel).
? *Pontoeciella abyssicola* (T. Scott).
Vettoria granulosa (Giesbr.) (= *Corina granulosa*)
Pachysoma tuberosum Giesbr.
P. punctatum Claus.
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
Miracia efferata Dana.
Macrosetella gracilis (Dana).
M. oculata Sars.
Clytemnestra scutellata Dana.
C. rostrata (Brady).
Ægisthus aculeatus Giesbr.
A. mucronatus Giesbr.
? *A. spinulatus* Farran.

In the Pacific Ocean there is a considerable difference in the facility with which warm-water species can be carried from the tropical region of the American coast westwards to the Asiatic coast in the north and south equatorial currents on the one hand, and in the opposite direction from the western tropical and sub-tropical regions eastward to the coasts of North and South America respectively. Throughout the tropical belt lie the wide north and south equatorial currents running from east to west, and though between them lies the warm contra-equatorial current, the extent of this is considerably less (*vide* Chart I). In the northern hemisphere there is a continuous current system flowing eastward that is formed by the Kuro-Siwo current, the North Pacific Drift and the California current off the west coast of North America, but this stream passes far to the north and gradually becomes cooled, so that the last part of the great circular movement, the California Current, is a cool one. In the southern hemisphere the difficulty of passing from west to east is even greater, for the warm East Australian Current, that swings eastward past New Zealand, runs in close apposition to the West Wind Drift, and finally this latter current sends a large branch that turns northwards and runs along the South American coast, where it is known as the Humbolt Current: this last mass of water is a cold one and carries with it a sub-antarctic fauna. In conformity with these differences in the local conditions on the western side of North and South America, it is found that there are marked differences in the Copepod fauna of the two regions. Esterly (1905, 1924), McMurrich (1916) and Campbell (1929) recorded 50 species from the west coast of North

America between the Tropic of Cancer and lat. 50° N., and Dana (1847–49) and Giesbrecht (1892) provided records of 42 species that have been taken off the west coast of South America south of lat. 10° S. and thus in the region of the Humbolt Current. I give below a list of the species that are now known to be present in these two, north and south, regions of the East Pacific, our knowledge of which has recently been greatly augmented by Wilson (1942), who has reported on the collections made by the "Carnegie":

Species from the W. coast of North America between lats. 23°–50° N.	Species from the W. coast of South America between lats. 10°–50° S.
Calanus cristatus Kröyer.	. .
C. finmarchicus (Gunn.).	. .
C. hyperboreus Kröyer.	. .
? *C. propinquus* Brady.	. .
C. tonsus Brady.	*Calanus tonsus* Brady.
Canthocalanus pauper (Giesbr.).	*Canthocalanus pauper* (Giesbr.).
Nannocalanus minor (Claus).	*Nannocalanus minor* (Claus).
. .	*Undinula caroli* (Giesbr.) (= *U. darwini*, (Lubb.)).
Undinula darwini (Lubb.).	*U. darwini* (Lubb.).
U. vulgaris (Dana).	*U. vulgaris* (Dana).
Eucalanus bungii Giesbrecht.	. .
E. bungii californicus Johnson.	. .
E. crassus Giesbr.	*Eucalanus crassus* Giesbr.
E. monachus Giesbr.	*E. monachus* Giesbr.
E. mucronatus Giesbr.	. .
. .	*E. pileatus* Giesbr.
. .	*E. subcrassus* Giesbr.
E. subtenuis Giesbr.	. .
. .	*Rhincalanus cornutus* f. *typica* Dana.
Mecynocera clausi Thompson.	*Mecynocera clausi* Thompson.
Paracalanus aculeatus Giesbr.	*Paracalanus aculeatus* Giesbr.
P. parvus (Claus).	*P. parvus* (Claus).
? *P. pygmæus* Claus.	. .
Acrocalanus gibber Giesbr.	. .
A. gracilis Giesbr.	*Acrocalanus gracilis* Giesbr.
A. longicornis Giesbr.	*A. longicornis* Giesbr.
A. monachus Giesbr.	. .
Calocalanus pavo (Dana).	*Calocalanus pavo* (Dana).
C. plumulosus (Claus).	*C. plumulosus* (Claus).
C. styliremis Giesbr.	*C. styliremis* Giesbr.
Clausocalanus arcuicornis (Dana).	*Clausocalanus arcuicornis* (Dana).
C. furcatus (Brady).	*C. furcatus* (Brady).
Ctenocalanus vanus Giesbr.	. .
Pseudocalanus minutus Kröyer.	*Pseudocalanus minutus* Kröyer.
Microcalanus pusillus Sars.	*Microcalanus pusillus* Sars.
M. pygmæus Sars.	*M. pygmæus* Sars.

Species from the W. coast of North America between lats. 23°–50° N.	Species from the W. coast of South America between lats. 10°–50° S.
..	*Drepanopus forcipatus* Giesbr.
Euchæta acuta Giesbr.	*Euchæta acuta* Giesbr.
E. marina (Prestand.).	*E. marina* (Prestand.).
Scolecithrix danæ (Lubb.).	*Scolecithrix danæ* (Lubb.).
Scolecithricella bradyi (Giesbr.).	*Scolecithricella bradyi* (Giesbr.).
..	*S. minor* (Brady).
..	*Centropages brachiatus* (Dana).
Centropages bradyi Wheeler.	..
C. calaninus (Dana).	*C. calaninus* (Dana).
C. elongatus Giesbr.	*C. elongatus* Giesbr.
..	*C. furcatus* (Dana).
C. hamatus (Lillj.).	..
C. mcmurrichi Willey.	..
..	*Temora discaudata* Giesbr.
..	*T. stylifera* (Dana).
Pseudodiaptomus (*Pseudodiaptallous*) *euryhyalinus* Johnson.	..
Eurytemora hyrundoides (Nordquist).	..
E. johanseni Willey.	..
E. transversalis Campbell (= *americana* Williams).	..
..	*Lucicutia flavicornis* (Claus).
Candacia æthiopica Dana.	*Candacia æthiopica* Dana.
C. bipinnata Giesbr.	*C. bipinnata* Giesbr.
C. bispinosa Claus.	*C. bispinosa* Claus.
C. columbiæ Campbell.	..
C. curta Dana.	*C. curta* Dana.
C. pectinata Brady.	..
C. simplex Giesbr.	*C. simplex* Giesbr.
C. truncata Dana.	*C. truncata* Dana.
..	*Labidocera acuta* (Dana).
Labidocera acutifrons (Dana).	*L. acutifrons* (Dana).
L. detruncata (Dana).	*L. detruncata* (Dana).
L. jollæ Esterly.	..
L. lubbocki Giesbr.	..
L. trispinosa Esterly.	..
Paralabidocera amphitrites McMurrich.	..
Pontella atlantica (M. E.)	*Pontella atlantica* (M. E.).
..	*P. danæ* Giesbr.
..	*P. fera* Dana.
P. lobiancoi Giesbr.	..
..	*P. princeps* Dana.
P. securifer Brady.	*P. securifer* Brady.

Species from the W. coast of North America between lats. 23°–50° N.	Species from the W. coast of South America between lats. 10°–50° S.
P. tenuiremis Giesbr.	*P. tenuiremis* Giesbr.
Anomalocera patersoni Templ.	..
Pontellopsis occidentalis Esterly.	..
..	*Pontellopsis regalis* (Dana).
Pontellina plumata Dana.	*Pontellina plumata* Dana.
Acartia clausi Giesbr.	..
A. danæ Giesbr.	*Acartia danæ* Giesbr.
..	*A. denticornis* Brady.
..	*A. lilljeborgi* Giesbr.
A. longiremis (Lillj.).	..
A. negligens Dana.	*A. negligens* Dana.
Tortanus discaudatus (Thomp. and A. Scott).	..
Oithona atlantica Farran.	*Oithona atlantica* Farran.
..	*O. attenuata* Farran.
O. brevicornis Giesbr.	*O. brevicornis* Giesbr.
O. nana Giesbr.	*O. nana* Giesbr.
O. plumifera Baird.	*O. plumifera* Baird.
O. similis Claus.	*O. similis* Claus.
Oncæa borealis Sars.	..
O. conifera Giesbr.	..
..	*Oncæa curta* Sars.
..	*O. curvata* Giesbr.
..	*O. dentipes* Giesbr.
O. media Giesbr.	*O. media* Giesbr.
..	*O. mediterranea* Claus.
O. minuta Giesbr.	*O. minuta* Giesbr.
..	*O. notopus* Giesbr.
..	*O. similis* Sars.
O. subtilis Giesbr.	*O. subtilis* Giesbr.
..	*O. tenella* Sars.
O. venusta Philippi.	*O. venusta* Philippi.
Lubbockia aculeata Giesbr.	*Lubbockia aculeata* Giesbr.
L. squillimana Claus.	*L. squillimana* Claus.
Corycæus agilis Dana.	*Corycæus agilis* Dana.
..	*C. andrewesi* Farran.
C. anglicus Lubb.	..
C. catus F. Dahl.	*C. catus* F. Dahl.
C. clausi F. Dahl.	*C. clausi* F. Dahl.
C. crassiusculus Dana.	*C. crassiusculus* Dana.
C. flaccus Giesbr.	*C. flaccus* Giesbr.
C. furcifer Claus.	*C. furcifer* Claus.
..	*C. giesbrechti* F. Dahl.

Species from the W. coast of North America between lats. 23°–50° N.	Species from the W. coast of South America between lats. 10°–50° S.
C. gracillicauda Giesbr.	*C. gracillicauda* Giesbr.
C. lautus Dana.	*C. lautus* Dana.
C. limbatus Brady.	*C. limbatus* Brady.
C. longistylis Dana.	*C. longistylis* Dana.
C. obtusus Dana.	*C. obtusus* Dana.
C. ovalis Claus.	*C. ovalis* Claus.
..	*C. pacificus* F. Dahl.
C. pumilus M. Dahl.	*C. pumilus* M. Dahl.
C. robustus Giesbr.	*C. robustus* Giesbr.
C. speciosus Dana.	*C. speciosus* Dana.
C. typicus Kröyer.	*C. typicus* Kröyer.
C. (*Corycella*) *carinatus* Giesbr.	*C.* (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *concinnus* Dana.	*C.* (*C.*) *concinnus* Dana.
..	*C.* (C.) *curtus* Farran.
C. (C.) *gibbulus* Giesbr.	*C.* (C.) *gibbulus* Giesbr.
..	*C.* (C.) *gracilis* Dana.
C. (C.) *rostratus* Claus.	*C.* (C.) *rostratus* Claus.
Sapphirina angusta Dana.	*Sapphirina angusta* Dana.
S. auronitens Claus—*sinuicauda* Brady.	*S. auronitens* Claus—*sinuicauda* Brady.
S. iris Dana.	*S. iris* Dana.
S. metallina Dana.	..
S. nigromaculata Claus.	*S. nigromaculata* Claus.
S. opalina Dana—*darwini* Haeckel.	*S. opalina* Dana—*darwini* Haeckel.
S. scarlata Giesbr.	..
Copilia mediterranea (Claus).	*Copilia mediterranea* (Claus).
..	*C. quadrata* Dana.
? Pontoeciella abyssicola (T. Scott).*	..
Vettoria granulosa (Giesbr.).	*Vettoria granulosa* (Giesbr.).
Pachysoma punctatum Claus.	*Pachysoma punctatum* Claus.
P. tuberosum Giesbr.	..
Microsetella norvegica (Boeck).	*Microsetella norvegica* (Boeck).
M. rosea Dana.	*M. rosea* Dana.
..	*Euterpina acutifrons* (Dana).

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* Wilson (1942) has described two new genera, each containing a single species, namely, *Carnegiella gracilis* and *Danodes plumata*; in each case he states that he had examples of the female only. A comparison of Wilson's description and figures of *Carnegiella gracilis* (Wilson, 1942, p. 176, figs. 20–25) with those given by T. Scott (1894. p. 129, pl. xii, figs. 5–9) and Farran (1936, p. 125, figs. 24 d and e) of the male of *Pontoeciella abyssicola* T. Scott reveals such a high degree of similarity that I have no doubt that Wilson had before him a male of a species of *Pontœciella* and probably a specimen of *P. abyssicola.* Similarly Wilson's description and figures of the female of *Danodes plumata* (Wilson, 1942, p. 182, figs. 57–68) show a close agreement with the female of *Pontœciella abyssicola* T. Scott, as described by T. Scott (1894, p. 128, pl. xiv, figs. 11–18) and by Giesbrecht (1899, p. 20, pl. v, figs. 15–27). It thus seems highly probable that Wilson had before him examples of both sexes of a species of *Pontœciella*, possibly *P. abyssicola*, and, if this be the case, the two genera *Carnegiella* and *Danodes* must be relegated to the list of synonyms of *Pontœciella.*

Species from the W. coast of North America between lats. 23°–50° N.	Species from the W. coast of South America between lats. 10°–50° S.
Macrosetella gracilis (Dana).	*Macrosetella gracilis* (Dana).
. .	*M. oculata* Sars.
Miracia efferata Dana.	. .
Clytemnesta rostrata (Brady).	*Clytemnestra rostrata* (Brady).
C. scutellata Dana.	*C. scutellata* Dana.

Some of the above records are open to doubt. The presence of *Calanus propinquus* Brady, which is an Antarctic form, in the upper stratum of the North Pacific Ocean seems highly improbable. Wilson's (1942) record of the occurrence of *Paracalanus pygmæus* (Claus) also appears to be doubtful: this species was most imperfectly described by Claus (1936), and the main feature by which he separated the species from others of the genus, namely the presence of three segments in the 5th leg of the female, is known to occur as an abnormality in both *Paracalanus aculeatus* (*vide* Sewell, 1929) and *P. parvus* (*vide* Norman and T. Scott, 1906). As regards yet another species, *Corycæus obtusus* Dana, M. Dahl (1912) holds that several species have been confused under this name; thus the specific identity of the forms from the north and south regions of the west coast of America must remain in doubt.

Of the 115 species recorded from the northern region, four are as yet unknown from elsewhere and are in all probability endemic; these are:

Candacia columbiæ Campbell.
Pontellopsis occidentalis Esterly.
Labidocera jollæ Esterly.
Pontella lobiancoi Giesbr.

A number of species have been recorded from the Arctic regions by T. Scott (1899), Sars (1900 and 1909), T. and A. Scott (1901), Mrazek (1902), Willey (1920 and 1932), and Jespersen (1923, 1934, 1937 and 1939), and several of these appear to have been swept southwards and have been taken in the northern part of the Pacific Ocean. Graham (1943) has pointed out that at one of the "Carnegie" Stations in the North Pacific (Sta. 122) there was an admixture of cold water of low salinity that had come in from the Bering Sea, and Wilson (1942) reports that at this station the following 21 species of Copepoda were captured:

Acrocalanus gracilis Giesbr.
**Calanus cristatus* Kröyer.
**C. finmarchicus* (Gunn.).
**C. hyperboreus* Kröyer.
Clausocalanus arcuicornis (Dana).
Eucalanus attenuatus (Dana).
E. elongatus (Dana).
Euchæta acuta Giesbr.
**Gaidius tenuispinus* Sars.
**Metridia longa* (Lubb.).
M. lucens Boeck.

Microsetella rosea Dana.
Neocalanus gracilis (Dana).
N. robustior Giesbr.
**Oithona similis* Claus.
Oncæa minuta Giesbr.
Paracalanus parvus (Claus).
P. pygmæus (Claus).
**Pseudocalanus minutus* Kröyer.
Scolecithricella bradyi (Giesbr.).
S. porrecta (Giesbr.).

Of the above species at least seven, marked with an asterisk, are known to be inhabitants of Arctic waters, and there seems to be little doubt that these have been swept southwards through the Bering Sea. A number of these and other species, that are known from the Arctic region, have been taken in the north Pacific area in the surface stratum and the full list is as follows :

Calanus cristatus Kröyer.
C. finmarchicus (Gunn.).
C. hyperboreus Kröyer.
C. tonsus Brady.
Ctenocalanus vanus Giesbr.
Pseudocalanus elongatus (Boeck) (= *minutus* Kröyer and *gracilis* Sars).
Microcalanus pusillus Sars.
M. pygmæus Sars.
Centropages hamatus (Lillj.).
C. mcmurrichi Willey.
Eurytemora americana Williams.
E. hyrundoides (Nordquist).
E. johanseni Willey.
Anomalocera patersoni Templ.
Paralabidocera amphitrites McMurrich.
Tortanus discaudatus Thomp. and A. Scott.
Acartia clausi Giesbr.
A. longiremis (Lillj.).
Oithona similis Claus.
O. spinirostris Claus (= *attenuata* Farran).
Oncæa borealis Sars.

Some of the above species appear to have been able to penetrate further to the south than others ; thus

Calanus tonsus Brady,
Pseudocalanus elongatus (Boeck),
Microcalanus pusillus Sars,
Centropages hamatus (Lillj.),
C. mcmurrichi Willey,
Eurytemora americana Williams (as *E. transversalis* Campbell),
Oithona similis Claus,

O. spinirostris Claus,
Acartia longiremis (Lilli.),
Oncœa borealis Sars,

have been recorded from the region of Vancouver Island, while

Calanus finmarchicus (Gunn.),
Paralabidocera amphitrites McMurrich,
Eurytemora hirundoides (Nordquist),
Acartia clausi Giesbr.,
Tortanus discaudatus Thomp. and A. Scott,

have got as far as the San Francisco region. Willey (1920, p. 45) has remarked, " there is an inexhaustible supply of this fish food in the Arctic Ocean, whence it filters down into the Northern Seas." In this region it is, however, difficult to correlate this southward movement of the surface plankton with the general drift of the surface-water. Recent work in the Arctic Ocean and the Bering Sea seems to indicate that there is, at least in the main, a northward drift: Thompson, Zeusler and Goodman (1940) state that there is a general northward movement of the waters from the Pacific Ocean into the Bering Sea through the passes formed by the Aleutian Islands, and in the western part of the Bering Strait between St. Lawrence Island and the Asiatic coast there seems to be a northerly movement of the water at all times of the year. The same observers (*vide* Goodman, Thompson and Zensler, 1940) indicate that on the east side of the Bering Strait off the American coast there is also a northward movement of the surface-water past Kotzebue Sound towards Point Barrow. Only on the extreme west side of Bering Strait Siberian Arctic water appears to move somewhat towards the south, where it forms the Oya-shio current, and produces a variable eddy. It would thus appear probable that the southward movement of the arctic plankton into the north Pacific area must be brought about by movement of this water in the Oya-shio Current.

This southerly drift from the Arctic Ocean into the north-western region of the Pacific Ocean seems to account for the occurrence of the following species round Japan:

Calanus cristatus Kröyer.
C. finmarchicus (Gunn.).
Pseudocalanus elongatus (Boeck).
Ctenocalanus vanus Giesbr.
Eurytemora pacifica Sato (? = *johanseni* Willey).
Centropages hamatus (Lillj.)*
Anomalocera patersoni Templ.
Acartia clausi Giesbr.†
A. longiremis (Lillj.).
Oithona similis Claus.
Microsetella norvegica Boeck.

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* It is possible that this record should be *Centropages mcmurrichi* Willey. McMurrich (1919) in his record of the occurrence of this species gave it under the name *C. hamatus* (Lillj.), though he noted that there were certain small differences in his specimens, and Willey (1920) created the new species *C. mcmurrichi* to accommodate these examples and others that he obtained off Alaska.

† This species was originally recorded by Marukawa (1921) under the name *Acartia bifilosa* Giesbr.; but Steuer (1933) has pointed out that the record in all probability refers to *A. clausi* Giesbr.

All these species have probably been carried southwards by the Oya-shio Current, especially in the winter months (*vide* Schott, 1935, Pl. XXIX), and may then have been caught up in the North Pacific Drift and so have been swept eastwards towards the American Coast. Recent work off the Californian coast (*vide* Thompson and Goodman (1940), and Fleming (1940)), has indicated that between the Californian Current and the coast there is commonly a flow to the north, termed the Californian counter-current, that can be traced between lats. 25° and 45° N.; but during the spring this current may disappear on the surface and upwelling takes place from about 200 m. depth; below 200 m. the counter current still persists. Species may thus be caught up in the counter-clockwise movement of the Alaska Current, and be swept first westward around the coast of Alaska and then northwards through the Bering Strait to the Arctic Ocean. Steuer (1933, p. 280) has suggested that both *Tortanus discaudatus* Thompson and A. Scott in the northern hemisphere and *Acartia lilljeborgi* Giesbr. in the southern hemisphere are coastal forms that in the Tertiary epoch inhabited the Atlantic and Indo-Pacific Oceans before the Isthmus of Panama was formed and cut off the connection between the two oceans, and that since then *Tortanus discaudatus* has migrated northwards towards the pole on both sides of the North American continent, so that to-day it is a boreal-atlantic and boreal pacific form; *Acartia lilljeborgi* on the other hand he supposes to have migrated southwards on both sides of the South American continent. It seems much more probable, so far as *Tortanus discaudatus* is concerned, that this species is a boreal-arctic form, and like *Eurytemora hyrundoides* (Nordquist) has been swept southwards from the Arctic Ocean through the Bering Strait to the west coast of North America and by the Labrador Current through Baffin Bay and Davis Strait to the Gulf of St. Lawrence and Puget Sound, where it was originally discovered.

Turning now to the species that have been recorded from the west coast of South America and the adjoining area of the South Pacific Ocean, we find that out of a total of 111 species, 94, or 85 per cent., are known from the tropical and south-western regions of the Pacific, and yet as many as 35 species have not so far been recorded from the north-eastern area, namely:

Undinula caroli (Giesbr.).*
Eucalanus pileatus Giesbr.
E. subcrassus Giesbr.
Drepanopus forcipatus Giesbr.
Rhincalanus cornutus Dana.
Scolecithricella minor (Brady).
Centropages brachiatus (Dana).
C. furcatus (Dana).
Temora discaudata Giesbr.
T. stylifera (Dana).
Lucicutia flavicornis (Claus).
Labidocera acuta (Dana).
Pontella danæ Giesbr.
P. fera Dana.

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* As I have previously pointed out, this "species" is in my opinion a variety of *Undinula darwini* (*vide* Sewell, 1929, p. 46).

P. princeps Dana.
Pontellopsis regalis (Dana).
Acartia denticornis Brady.
A. lilljeborgi Giesbr.
Oithona attenuata Farran.
Oncœa curta Sars.
O. curvata Giesbr.
O. dentipes Giesbr.
O. mediterranea Claus.
O. notopus Giesbr.
O. similis Sars.
O. tenella Sars.
O. venusta Philippi.
Corycæus andrewesi Farran.
C. giesbrechti F. Dahl.
C. pacificus F. Dahl (? = *obtusus* Dana).
C. (*Corycella*) *curtus* Farran.
C. (*C.*) *gracilis* Dana.
Copilia quadrata Dana.
Euterpina acutifrons (Dana).
Macrosetella oculata Sars.

Of the above species 23 are known to occur in the south-west region of the Pacific, and possibly a twenty-fourth, *Corycæus* (*Corycella*) *gracilis*, is to be found there, though the record of this is doubtful: 23 species occur in the Indian Ocean and 24 in the Atlantic. It is thus clear that many of them are hardy species, capable of surviving considerable changes in the character of their habitat; and this is especially true of those species that are to be found in the Atlantic Ocean, since in their passage westward, if this took place in geologically recent times, they must have been able to survive transfer across the region of admixture of warm and cold water off South Africa, where the Benguela current has its origin. It is thus possible that these species have not originated in the south-east Pacific area, but have been swept eastward from the south-west region or even from further west from the Indian Ocean, and have managed to survive in the cold water of the West Wind Drift and the Humbolt Current. Such a transfer would be in keeping with the suggestion put forward by Cleve (1904) that the explanation of the presence of a number of species in both the Agulhas Current off the south-east corner of Cape Colony and off the west coast of South America is due to the steady flow of the mingled waters of the Agulhas Current and the West Wind Drift eastward across the southern part of the Pacific Ocean to the Humboldt Current. If this were so we should expect to find most, if not all, of these species present on the south coast of Australia; from this region we have records (*vide* Brady, 1883, and Nicholls, 1944) of the following:

**Nannocalanus minor* (Claus) (as *Calanus valgus*).
**Undinula darwini* (Lubb.).
**U. vulgaris* (Dana).
**Acrocalanus gracilis* Giesbr.
**Clausocalanus furcatus* (Brady).

**Euchæta marina* (Prestand.) (as *E. prestandrea*).
**Centropages violaceus* (Claus).
**Gladioferens brevicornis* Henry.
G. inermis Nicholls.
**Temora stylifera* (Dana).
Pseudodiaptomus cornutus Nicholls.
**Pseudocyclops australis* Nicholls.
**Calanopia thompsoni* A. Scott.
**Candacia pectinata* Brady.
**Labidocera cervi* Krämer.
L. caudata Nicholls.
Acartia denticornis Brady.
**Tortanus barbatus* (Brady).
Oithona attenuata Farran.
**O. nana* Giesbr.
Oncæa obtusa Dana (? = *O. venusta* Philippi).
**Corycæus speciosus* Dana (as *C. varius*).
Sapphirina ovalis Dana.
**Copilia mirabilis* Dana.
**Macrosetella gracilis* (Dana).

A comparison of the above list with that of the species that have been recorded from the southern region of the east Pacific Ocean, but have not as yet been taken in the northern area, shows that only three are common to both lists, namely *Temora stylifera* (Dana), *Oithona attenuata* Farran and the doubtful species *Acartia denticornis* Brady, and possibly a fourth, *Undinula darwini* (Lubb.), if I am right in thinking that *U. caroli* Giesbr. is a synonym. Six of the South Australian species are peculiar to this region or the Tasman Sea, namely :

Gladioferens brevicornis Henry,
G. inermis Nicholls,
Pseudodiaptomus cornutus Nicholls,
Pseudocyclops australis Nicholls,
Labidocera cervi Krämer,
L. caudata Nicholls,

and these are probably endemic. Seven species have been recorded from the West Wind Drift, namely *Nannocalanus minor* (Claus), *Undinula darwini* (Lubb.), *Clausocalanus furcatus* (Brady), *Euchæta marina* (Prestand.), *Centropages violaceus* (Claus), *Corycæus speciosus* Dana and *Macrosetella gracilis* (Dana), and to these may be added the doubtful species *Acartia denticornis* Brady ; these species may perhaps have reached the south coast of Australia from the west, during that part of the year in which the main trend of the current in the coastal region is from west to east, namely August and September (*vide* Schott, 1935, pl. xxx), but as many as 18, marked with an asterisk, have been recorded by Dakin and Colefax (1933) and Henry (1919) from New South Wales and, with the exception of *Gladioferens brevicornis*, that is a fresh- or brackish-water form, all of them are known to be inhabitants of the south-west Pacific area, and in addition *Oithona attenuata* Farran is known from the same region, and there can be little doubt that they have reached their habitat on the South Australian coast in the branch of the East Australian Current that turns westward along the south coast of Australia during the months February–March and later (*vide* Schott, 1935, pl. xxix).

I think therefore that it is much more probable that the transfer of most of the 24 species that are known from the south area of the east Pacific region, but not from the north area, has been brought about from east to west in the South Equatorial Current, though the following species may possibly be exceptions to this, namely :

Drepanopus forcipatus Giesbr.
Scolecithricella minor (Brady).
Centropages brachiatus (Dana).
Acartia Lilljeborgi Giesbr.
Oncœa curvata Giesbr.
O. notopus Giesbr.
Corycœus (*Corycella*) *gracilis* Dana.
Euterpina actifrons (Dana).

All of these are known to be inhabitants of the West Wind Drift (*vide infra*, p. 453). *Drepanopus forcipatus* Giesbr. and *Acartia lilljeborgi* Giesbr. have been recorded from both west and east coasts of South America, and Steuer (1933) has attempted to explain the distribution of the latter species by assuming that it was in existence in the Tertiary epoch, when there was a direct communication between the Atlantic and Pacific Oceans across Central America, and that the species migrated southwards from the tropics along both coasts; this explanation, however, assumes that the migration was carried out against the trend of the currents, as they flow to-day, on both, but especially on the west side of South America. In the genus *Drepanopus* the only other known species, *D. pectinatus* Brady, is a denizen of the Sub-polar Antarctic region and the West Wind Drift, and has been recorded as present in large numbers round the Falkland Islands, South Georgia and Kerguelen, and it seems probable that *D. forcipatus* has a similar habitat, and that both it and *Acartia lilljeborgi* have been swept northwards up the west coast of South America by the branch of the West Wind Drift that forms the Humboldt Current and up the east coast in the Falkland Island Current, though this does not at the present time run as far to the north as the position in which *Acartia lilljeborgi* has been taken.

As regards *Oncœa notopus* Giesbr., it is much more likely that it is a tropical form that has managed to penetrate into the West Wind Drift, since it has been recorded from the warm water of the Japanese coast in the Pacific Ocean and from the tropical region of the Indian Ocean, and even as far north as the Gulf of Suez. That it is an extremely hardy species is shown by the fact that it has been recorded by Sars from the New Siberian Islands in the Arctic Ocean, and is stated by Hardy and Günther (1935, p. 192) to be widespread in the Antarctic, extending across the Antarctic convergence towards the Falkland Islands. On the other hand *Oncœa curvata* Giesbr. may be an Antarctic species that has spread northwards across the Antartic convergence into the West Wind Drift and so has reached the south-east Pacific area.

Between the north and south Pacific regions lies the region of the Counter-equatorial Current that flows from west to east. From this belt, thanks to the work of Giesbrecht (1892) and Wilson (1942), as many as 137 species have been recorded ; of these 102 are known from the west Pacific region, and their presence can thus be accounted for by transference eastward from the Asiatic to the American side of the ocean. Along both margins of the current lie the tropical convergence zones, in which there is some, and possibly a considerable, mixing of the water with the north and south Equatorial currents, and this may account for the presence in the Contra-Equatorial Current of the species *Scolecithricella minor* (Brady), *Temora stylifera* (Dana) and *Oncœa curta* Sars, which have been recorded from the southern area of the Pacific but are as yet unknown from either the northern or western areas, and *Corycœus clausi* F. Dahl and *C. anglicus* Lubb., which have been recorded by Wilson (1942) from the northern and central areas of the east Pacific Ocean but are unknown from the southern or western regions. A few of Wilson's records, however, appear to be open to doubt ; he has recorded from the Pacific Ocean the following species :

Calanus propinquus Brady.
Oncœa anglica Brady.
O. similis Sars.
O. tenella Sars.
Corycœus anglicus Lubb.
Ægisthus spinulosus Farran.

Calanus propinquus is an Antarctic species and the other five have previously only been recorded from the North Atlantic Ocean or its offshoots ; if their presence in the Pacific Ocean be confirmed, the explanation may be found in the existence of the open connection between the Atlantic and Pacific Oceans in Tertiary times, or else in their transference through the Arctic region.

Four species, namely,

Euchæta flava Giesbr.,
E. grandiremis Giesbr.,
Labidocera lubbocki Giesbr.,
Pontella agassizi Giesbr.,

have up to the present time only been recorded from the tropical region of the east Pacific and may be regarded as endemic ; this is especially true of *Labidocera lubbocki*, which was originally recorded from the estuary of the Guayaquil River and is thus an inhabitant of brackish water. A fifth species that appears to be endemic in this region is *Pseudodiaptomus culebrensis* Marsh but this is a fresh-water form. A single species, *Vettoria granulosa* (Giesbr.) (= *Corina granulosa*) is at present known only from the tropical eastern Pacific region, the Mediterranean Sea and the coast of Ireland, and a possible explanation of this discontinuous distribution may lie in the connection that existed in Tertiary times between the Pacific and Atlantic Oceans through the Tethys Sea.

I have already pointed out that the North and South Equatorial Currents provide a highway along which planktonic organisms can be swept westwards from the East Pacific region ; we should therefore expect to find that many of the warm-water species from the coast of North America and the neighbouring area of the North Pacific Ocean have been carried westward to the west Pacific area in the region of the Philippine Islands, and from thence they can be swept northwards by the Kuro-Siwo Current and its branches and so reach the region round Japan. Our knowledge of the Japanese fauna was still very incomplete until Wilson (1942) published his report on the results of the " Carnegie " investigations. I have been able to collate references to 118 species from this area (*vide* Brady (1883), Marukawa (1908), Sato (1913), Mori (1929, 1932 and 1935), Kurasige (1931), Tanaka (1936, 1937) and Wilson (1942)).

The species present are as follows :

**Calanus cristatus* Kröyer.
**C. finmarchicus* Gunn.
C. ramosus Mori.†
C. syumpuensis Kurasige.
C. tenuicornis Dana.
Nannocalanus minor (Claus).
Canthocalanus pauper (Giesbr.).
Undinula caroli (Giesbr.).
U. darwini (Lubb.).
U. vulgaris (Dana).
U. vulgaris var. *plumulosus* (as *Calanus orientalis* Marukawa).
Eucalanus mucronatus Giesbr.
E. oculanus Marukawa (? = *E. crassus* Giesbr.).
E. setiger Brady.
E. subtenuis Giesbr.
Rhincalanus cornutus f. *typica* Dana.
Mecynocera clausi Thompson.
Paracalanus parvus (Claus).
? *P. pygmæus* (Claus).
Acrocalanus gibber Giesbr.
A. gracilis Giesbr.
A. longicornis Giesbr.
A. monachus Giesbr.
Calocalanus pavo (Dana).
C. plumulosus (Claus).
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
**Pseudocalanus minutus* Kröyer (= *elongatus* (Boeck)).
**Microcalanus pusillus* Sars.
**M. pygmæus* Sars.
**Ctenocalanus vanus* Giesbr.
Euchæta acuta Giesbr.
E. japonica Marukawa.
E. marina (Prestand.).
E. marina var. *longispinosa*.
Scolecithrix danæ (Lubb.).
Scolecithricella bradyi (Giesbr.).

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† This "species" appears to be based on an abnormal and, possibly, immature individual. The rounded posterior thoracic margin resembles that of *Undinula darwini* var. *symmetrica* Sewell, and the branched character of the furcal setæ is an abnormality that has been noticed in several species. It seems probable that this species is a synonym of *Undinula darwini*, just as *Calanus orientalis* Marukawa is a synonym of *Undinula vulgaris* (Dana) var. *plumulosus* Wolfend. (*vide* Früchtl, 1924, p. 15).

S. ovata (Farran).
Centropages abdominalis.
C. calaninus (Dana).
C. elongatus Giesbr.
C. furcatus (Dana).
**C. hamatus* (Lillj.).
C. longicornis Mori.
C. orsinii Giesbr.
C. violaceus Brady.
Temora discaudata Giesbr.
**T. longicornis* (Müll.).
T. turbinata (Dana).
**Eurytemora pacifica* Sars. (? = *E. johanseni* Willey).
Pseudodiaptomus marinus.
Lucicutia flavicornis (Claus).
Candacia æthiopica Dana.
C. bicornuta Mori.
C. bispinosa Claus.
C. bipinnata Giesbr.
C. catula Giesbr.
C. curta Dana.
C. curva Mori.
C. longimana Claus.
**C. norvegica* Boeck.
C. pachydactyla Dana.
C. pectinata Brady (= *armata* Boeck).
C. simplex Giesbr.
C. tenuimana Giesbr.
C. truncata Dana.
Labidocera acuta (Dana).
L. acutifrons (Dana).
L. bipinnata Tanaka (? = *L. pectinata* Thomp. and A. Scott).
L. detruncata (Dana).
L. japonica Mori.
L. rotunda Mori (? = *L. pectinata* Thomp. and A. Scott, ♂).
L. pavo Giesbr.
L. wollastoni (Lubb.).
Pontella atlantica (M. E.).
P. barbata Tanaka.
P. bifurvata Tanaka.
P. forcipata Tanaka.
P. longipedata Sato.
P. securifer Brady.
P. whiteleggei Krämer.
**Anomalocera patersoni* Templ.
Pontellopsis æqualis Mori.

**Acartia bifilosa* Giesbr. (probably *A. clausi* Giesbr.).
A. danæ Giesbr.
**A. longiremis* (Lillj.).
A. negligens Dana.
A. steueri Smirnov.
Oithona attenuata Farran.
O. nana Giesbr.
O. plumifera Baird.
O. setigera (Dana).
O. spinirostris Claus (= *O. atlantica* Farran).
Oncæa conifera Giesbr.
O. curvata Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. minuta Giesbr.
**O. notopus* Giesbr.
O. obtusa Brady.
O. similis Sars.
O. tenella Sars.
O. venusta Philippi.
Corycæus (*Corycæus*) *speciosus* Dana.
C. (*C.*) *crassiusculus* Dana.
C. (*Monocorycæus*) *robustus* Giesbr.
C. (*Agetes*) *typicus* Kröyer.
C. (*Urocorycæus*) *lautus* Dana.
C. (*U.*) *longistylis* Dana.
C. (*Ditrichocorycæus*) *dubius* Farran.
C. (*D.*) *lubbocki* Giesbr.
C. (*Onychocorycæus*) *obtusus* Giesbr.
C. (*O.*) *ovalis* Claus.
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *curtus* Farran.
C. (*C.*) *gibbulus* Giesbr.
C. (*C.*) *rostratus* Claus.
Lubbockia aculeata Giesbr.
L. squillimana Claus.
Sapphirina angusta Dana.
S. auronitens Claus—*sinuicauda* Brady.
S. metallina Dana.
S. ovatolanceolata Dana—*gemma* Dana.
S. stellata Giesbr.
Copilia longistylis Mori.
C. mediterranea (Claus).
C. mirabilis Dana.
C. recta Giesbr.
Pachysoma dentatum Mori.

P. tuberosum Giesbr.
Microsetella norvegica (Boeck).
M. rosea Dana.
Macrosetella gracilis (Dana).
M. oculata Sars.
Euterpina acutifrons (Dana).
Miracia efferata Dana.
Clytemnestra scutellata Dana.

Several of the above species are known to be inhabitants of the Arctic Ocean and can have been drifted southwards, probably in the Oya-Shio Current ; these I have indicated by an asterisk.

Twelve species appear up to the present time to be confined to the Japanese region and are possibly endemic ; these are as follows :

? *Calanus ramosus* Mori.
C. syumpuensis Kurasige.
Pseudodiaptomus marinus.
Centropages longicornis Mori.
Labidocera japonica Mori.
Pontella barbata Tanaka.
Pontellopsis æqualis Mori.
Acartia steueri Smirnov.
Candacia bicornuta Mori.
Pontellopsis æqualis Mori.
Copilia longistylis Mori.
Pachysoma dentatum Mori.

The western tropical region of the Pacific Ocean is directly connected with the Indian Ocean by numerous channels that pass between the islands of the Malay Archipelago and between New Guinea and Australia. The direction in which the surface water flows through these channels depends in the main on the direction of the prevailing wind, and, in consequence of the alternation of the north-east and south-west monsoons, the current is reversed approximately every six months. One such channel connects the China Sea through the Strait of Malacca with the Andaman Sea and on through Preparis Channel, Ten Degree Channel and Great Channel with the Bay of Bengal and the Indian Ocean. In a previous paper (Sewell, 1929) I have pointed out that during the north-east monsoon in December–February the current flows in a westerly direction from the Pacific to the Indian Ocean. Michaelis (1923, chart 1) for the month of January and Schott (1936, pl. xxix) for the months February–March show a current of water flowing from the South China Sea through the Strait of Malacca into the Andaman Sea, while another stream of water passes through the Sunda Strait between Sumatra and Java into the Indian Ocean direct ; at the same time a current sets eastward from the Timor Sea and the region off the north-west part of Australia through the Torres Strait into the Coral Sea and the Pacific Ocean. During the south-west monsoon, from June to September, the direction of flow is reversed and we get a flow of water eastward across the Indian Ocean between lats. 0°–10° N., and from this an offshoot passes into the Andaman Sea and then through the Strait of Malacca to the western Pacific Ocean. Michaelis (1923, chart 2) and Schott

(1936, pl. xxx), however, show that during the months of July–September a current runs westward from the Java Sea through the Sunda Strait, and from the Coral Sea through the Torres Strait into the Indian Ocean and on to the African coast, where in part it joins the Agulhas Current. More recently Myers (1943), summarizing our knowledge of the movement of the water in these regions, states that the season of the west monsoon extends from December to April, and that this wind induces currents that pass through the narrow channels between the Thousand Islands, and that in at least occasional years a deep stream of water passes from the Indian Ocean through the Sunda Strait and continues along the north coast of Java as far as the Bay of Batavia. During the east monsoon season, extending from April to December, typically oceanic water enters the Java Sea from the Flores Sea and the Indian Ocean. Such an interchange of surface water not only permits but must actually bring about a corresponding interchange of planktonic organisms. Another route by which surface-living organisms may be carried from the south-west Pacific region into the Indian Ocean is by the East Australian Current that sets southwards down the east coast of Australia, and during the months of February–March (*vide* Schott, 1936, pl. xxix) sends a branch westward through the Bass Strait between Australia and Tasmania and another to the south of Tasmania ; this current flows westward along the south coast of Australia, and then turns northwards along the west coast to join the South Equatorial Current in the Indian Ocean. It seems probable, however, that only the more hardy species could survive along this southerly route for, as we trace the planktonic surface-living species from the tropical and sub-tropical regions of the West Pacific Ocean past the Great Barrier Reef to the south coast of Australia, there is a marked decrease in the number of recorded species ; out of a total of some 147 species recorded from the Malay Archipelago, 87 have been taken on the Great Barrier Reef, 78 have been recorded by Dakin and Colefax (1933) in the coastal waters of New South Wales, but so far only some 18 or 19 have been recorded from South Australia (*vide supra*, p. 403).

Taking the eastern Pacific fauna as a whole, out of a total of 188 species 11 have a range that extends westward across the Pacific and on into the Indian Ocean but have not as yet been recorded from beyond this latter region, namely,

Undinula caroli (Giesbr.) (? = *U. darwini* Lubb. var.),
Euchæta longicornis Giesbr.,
Pontella danæ Giesbr.,
Tortanus forcipatus (Giesbr.).,
Pontella princeps Dana,
Pachysoma tuberosum Giesbr.,
Corycæus (*Corycæus*) *vitreus* Dana,
C. (*Ditrichocorycæus*) *africanus* F. Dahl,
C. (*Onychocorycæus*) *pumilus* M. Dahl,
C. (*O.*) *pacificus* F. Dahl,
C. (*Corycella*) *concinnus* Dana,

and to these may be added *Labidocera trispinosa* Esterly, that has so far only been recorded from the eastern Pacific area and the Indian Ocean, though probably further investigations will reveal its presence in the western Pacific region also.

Fifty-one species have been able to extend their habitat into the Indian Ocean and on into the Red Sea, but have not been able to get as far north as the Gulf of Suez and the Suez Canal. These species are as follows :

Nannocalanus minor (Claus).
Undinula vulgaris (Dana).
Eucalanus crassus Giesbr.
E. pileatus Giesbr.
E. subcrassus Giesbr.
E. subtenuis Giesbr.
Rhincalanus cornutus f. *typica* Dana.
Mecynocera clausi Thompson.
Paracalanus aculeatus Giesbr.
Acrocalanus gracilis Giesbr.
A. longicornis Giesbr.
A. monachus Giesbr.
Calocalanus plumulosus (Claus).
Euchæta marina (Prestandr.).
Centropages gracilis (Dana).
Candacia æthiopica Dana.
C. bispinosa Claus.
C. catula Giesbr.
C. curta Dana.
C. simplex Giesbr.
C. truncata Dana.
Labidocera acutifrons (Dana).
Pontella fera Dana.
Pontellina plumata Dana.
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*Planktacartia*) *negligens* Dana.
Tortanus forcipatus (Giesbr.).
Oithona linearis Giesbr.
O. setigera (Dana).
Oncæa conifera Giesbr.
O. mediterranea Claus.
Lubbocki aculeata Giesbr.
Corycæus (*Corycæus*) *speciosus* Dana.
C. (*Monocorycæus*) *robustus* Giesbr.
C. (*Agetes*) *flaccus* Giesbr.
C.(*A.*) *typicus* Kröyer.
C. (*Urocorycæus*) *longistylis* Dana.
C. (*Onychocorycæus*) *agilis* Dana.
C. (*O.*) *catus* F. Dahl.
C. (*O.*) *obtusus* Dana (? = *catus* F. Dahl).
C. (*Corycella*) *carinatus* Giesbr.
Sapphirina auronitens Claus—*sinuicauda* Brady.

S. bicuspidata Giesbr.
S. metallina Dana.
S. nigromaculata Claus.
S. opalina Dana—*darwini* Haeckel.
S. scarlata Giesbr.
Copilia mirabilis Dana.
Microsetalla rosea Dana.
Macrosetella gracilis (Dana).
Ægisthus aculeatus Giesbr.

Twenty-five other species from the East Pacific area have, so far as our present records go, reached the Red Sea and have been carried as far north as the Gulf of Suez, namely :

Canthocalanus pauper (Giesbr.).
Undinula darwini (Lubb.).
Paracalanus parvus (Claus).
Acrocalanus gibber Giesbr.
Clausocalanus arcuicornis (Dana).
Centropages calaninus (Dana).
C. furcatus (Dana).
Temora discaudata Giesbr.
Lucicutia flavicornis (Claus).
L. stylifera (Dana).
Labidocera acuta (Dana).
Acartia clausi Giesbr.
A. negligens Dana.
Oithona nana Giesbr.
O. plumifera Baird.
O. similis Claus.
Oncœa media Giesbr.
O. minuta Giesbr.
O. venusta Philippi.
Corycæus (*Corycæus*) *crassiusculus* Dana.
Lubbockia squillimana Claus.
Microsetalla norvegica (Boeck).
Euterpina acutifrons (Dana).
Clytemnestra rostrata (Brady).
C. scutellata Dana.

Munro Fox (*vide* Gurney, 1927, p. 171) is of the opinion that *Acartia clausi* Giesbr. has reached the Suez Canal from the Mediterranean Sea ; it has, however, been recorded by Thompson (1900) from several stations in the Indian Ocean, the Bay of Bengal and the Red Sea.

In view of the fact that for about half the year there is a strong surface current setting through the Gulf of Aden and the Strait of Bab-el-Mandeb from the Arabian Sea to the Red Sea, it is at first sight somewhat surprising that, comparatively, so few of the surface-living Copepoda that are known to be present in the Arabian Sea have succeeded in getting into the Red Sea and reaching the Gulf of Suez and the Suez Canal. This subject will be dealt with later, when considering the distribution of the planktonic Copepoda of the Indian Ocean (*vide infra*, p. 432).

A very large number of the eastern Pacific species appears to have succeeded in reaching the tropical and south temperate regions of the Atlantic Ocean, in which the following have been recorded :

Nannocalanus minor (Claus).
Canthocalanus pauper (Giesbr.).
Undinula darwini (Lubb.).
U. vulgaris (Dana).
Eucalanus crassus Giesbr.
E. monachus Giesbr.
E. mucronatus Giesbr.
E. pileatus Giesbr.
E. subcrassus Giesbr.
E. subtenuis Giesbr.
Rhincalanus cornutus Dana.
Mecynocera clausi Thompson.
Paracalanus aculeatus Giesbr.
P. parvus (Claus).
Acrocalanus longicornis Giesbr.
Calocalanus pavo (Dana).
C. plumulosus (Claus).
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
Euchæta acuta Giesbr.
E. marina (Prestandr.).
E. media Giesbr.
E. philippi Brady.
Scolecithrix danæ (Lubb.).
Scolecithricella bradyi (Giesbr.).
S. minor (Brady).
Centropages brachiatus (Dana).
C. bradyi Wheeler.
C. calaninus (Dana).
C. furcatus (Dana).
C. gracilis (Dana).
Temora stylifera (Dana).
Lucicutia flavicornis (Claus).
Candacia æthiopica Dana.
C. bipinnata Giesbr.
C. bispinosa Claus.
C. curta Dana.
C. pachydactyla Dana.

C. pectinata Brady.
C. simplex Giesbr.
C. truncata Dana.
Labidocera acuta (Dana).
L. acutifrons (Dana).
L. detruncata (Dana).
Pontella atlantica (M. E.).
P. fera Dana.
P. securifer Brady.
Pontellopsis regalis (Dana).
Pontellina plumata Dana.
Acartia clausi Giesbr.
A. danæ Giesbr.
A. negligens Dana.
A. tonsa Dana.
Oithona atlantica Farran.
O. attenuata Farran.
O. brevicornis Giesbr.
O. nana Giesbr.
O. plumifera Baird.
O. setigera (Dana).
O. similis Claus.
Oncæa conifera Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. minuta Giesbr.
O. notopus Giesbr.
O. subtilis Giesbr.
O. venusta Philippi.
Conæa rapax Giesbr.
Lubbockia aculeata Giesbr.
L. squillimana Claus.
Corycæus (Corycæus) crassiusculus Dana.
C. (C.) speciosus Dana.
C. (Monocorycæus) robustus Giesbr.
C. (Agetes) flaccus Giesbr.
C. (A.) limbatus Brady.
C. (A.) typicus Kröyer.
C. (Urocorycæus) furcifer Claus.
C. (U.) lautus Dana.
C. (Onychocorycæus) agilis Dana.
C. (O.) catus F. Dahl.
C. (O.) giesbrechti F. Dahl.
C. (O.) ovalis Claus.
C. (Corycella) carinatus Giesbr.
C. (C.) gibbulus Giesbr.

C. (*C.*) *gracilis* Dana.
C. (*C.*) *rostratus* Claus.
Sapphirina angusta Dana.
S. auronitens Claus—*sinuicauda* Brady.
S. bicuspidata Giesbr.
S. iris Dana.
S. metallina Dana.
S. nigromaculata Claus.
S. opalina Dana—*darwini* Haeckel.
S. stellata Giesbr.
S. scarlata Giesbr.
Copilia lata Giesbr.
C. mediterranea (Claus).
C. mirabilis Dana.
C. quadrata Dana.
C. vitrea (Haeckel).
Pontœciella abyssicola (T. Scott).
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
Miracia efferata Dana.
Macrosetella gracilis (Dana).
M. oculata Sars.
Clytemnestra rostrata (Brady).
C. scutellata (Dana).
Ægisthus mucronatus Giesbr.
A. aculeatus Giesbr.

In the above list I have included *Candacia pectinata* Brady, which has not as yet been recorded from the south-west Pacific area though it has been taken in the region of Japan, and *Euchæta philippi* Brady and *Centropages bradyi* Wheeler, which are not known from the Indian Ocean; indeed the former species is of doubtful validity but I have included it here for the sake of completeness, and we may also add those other doubtful species, *Acartia laxa* Dana and *A. denticornis* Brady. If we include these additional species in the list of those that appear to have been carried westward at some time in the past into the Atlantic Ocean we have no less than 112 species that have undergone this transfer. We have already seen that 188 species have been recorded from the east Pacific region, but of these 19 may have been carried southwards into this area from the Arctic Ocean and 2 others have been swept northwards from the West Wind Drift; these 21 species therefore should not be regarded as true east Pacific species; this leaves us with 167 East Pacific species, and of these 112, or 67 per cent., have reached the Atlantic Ocean. So far as the available evidence goes, four of these species, namely,

Canthocalanus pauper (Giesbr.),
Centropages calaninus (Dana),
Pontella fera Dana,
Oithona attenuata Farran,

have only succeeded in getting into the south temperate region, and in this area *Corycella rostrata* Claus has given rise to a variety, var. *longa* Kleverhusen. Eight others, namely,

Undinula darwini (Lubb.),
Eucalanus pileatus Giesbr.,
E. subcrassus Giesbr.,
Candacia truncata Dana,
Corycæus (*Onychocorycæus*) *agilis* Dana,
C. (*Monocorycæus*) *robustus* Giesbr.,
C. (*Corycella*) *gibbulus* Giesbr.,
Clytemnestra rostrata (Brady),

have got as far as the tropical region. All the others have been recorded from the North Temperate region of the Atlantic.

As we pass westwards from the American coast across the Pacific we meet with numerous groups of islands, but our knowledge of the fauna of these regions is far from complete: several species of Copepod have, however, been recorded by Dana (1847–49), Streets (1877) and Giesbrecht (1892), and I give the position from which they have been recorded:

		Lat.	Long.
Candacia longimana Claus	from	16° N.	165° E.
C. tenuimana Giesbr.	,,	16° N.	166° E.
Pontellopsis armata (Giesbr.)	,,	10° N.	137° E.
P. villosa Brady	,,	30° N.	155° W.
Sapphirina gastrica Giesbr.	,,	19° N.	175° W.
S. intestinata Giesbr.	,,	11°–15° N.	143° E.

None of these species has, so far, been recorded from the East Pacific region, and it is possible that they have actually originated around these islands between lats. 10°–30° N. If this be so, they have, as a study of the surface currents indicates, been swept westward in the North Pacific Equatorial Current and so have reached the west Pacific region. From this region they have all been carried still further westward into the Indian Ocean, and *Candacia longimana* Claus has reached the Red Sea but has not got as far north as the Gulf of Suez. Both species of *Candacia*, *longimana* Claus and *tenuimana* Giesbr., *Pontellopsis villosa* Brady and *Sapphirina gastrica* Giesbr. have been carried as far westward as the Atlantic Ocean; the last two species have been taken in the Woods Hole region of the east coast of North America, and *Sapphirina gastrica* Giesbr. has got into the Mediterranean Sea. Similarly, in the region south of the Equator, Dana (1847–49) has recorded a number of species from the Polynesian and Micronesian regions: most of these are known from further east but two, namely *Pontellopsis strenua* Dana, recorded from lat. 3° S., long. 173° E., and *Oithona oculata* Farran, recorded by Rosendorn from Samoa, may have originated in this region and, if so, have probably been carried westward in the South Equatorial Current, and this would account for their presence in the west Pacific and Indian regions respectively.

Turning now to the tropical and temperate regions of the western part of the Pacific Ocean, thanks to the work of Brady (1883, 1899), Giesbrecht (1892), Krämer (1894), Cleve (1901), Sars (1905), Carl (1907), A. Scott (1909), Rosendorn (1912), Früchtl (1924), Farran (1929, 1936), Smith (1941), Wilson (1942), and Vervoort (1946), I have been able to collect references to 110 species that have so far not been recorded from further east, namely :

***Eucalanus dentatus* A. Scott.
Paracalanus crassirostris F. Dahl, var. *typicus* Früchtl.
P. denudatus Sewell.
Acrocalanus gardineri Wolfenden.
A. inermis Sewell.
Calocalanus contractus Farran.
***C. pavoninus* Farran.
Clausocalanus farrani Sewell.
C. paululus Farran.
C. pergens Farran.
Euchæta concinna Dana.
E. consimilis Farran.
E. pubera Sars.†
**E. russelli* Farran.
E. wolfendeni A. Scott.
**Xanthocalanus squamatus* Farran.
**Macandrewella asymmetrica* Farran.
**M. joanæ* A. Scott.
**M. mera* Farran.
**M. sewelli* Farran.
Scolecithricella dentata (Giesbr.).
S. nicobarica Sewell.
S. tenuiserrata (Giesbr.).
**Scolecocalanus galeatus* Farran.
Centropages auklandicus Krämer (= *C. discaudatus* Brady).
C. elongatus Giesbr.
C. kröyeri Giesbr.
C. orsinii Giesbr.
**Gladioferens pectinatus* (Brady) (= *Centropages pectinatus* Brady).
Temora longicornis (O. F. Müller).
T. turbinata (Dana) (? = *T. tenuicauda* Brady).
Temoropia mayumbæensis (T. Scott).
Pseudodiaptomus aurivillii Cleve.
P. clevei A. Scott.
**P. dauglishi* Sewell.
P. mertoni Früchtl.
Metacalanus aurivillii Cleve.
Candacia bradyi A. Scott.
C. discaudata A. Scott.
C. longimana Dana.
C. tenuimana Giesbr.

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† Sars (1925) and Rose (1933) regard *E. wolfendeni* A. Scott as a synonym of this species, but Farran (1929) dissents from this view.

C. varicans Giesbr.
Labidocera bataviæ A. Scott.
**L. bipinnata* Tanaka (? = *pectinata* Thomp. and A. Scott).
**L. cervi* Krämer.
**L. glauca* Smith.
L. kröyri (Brady).
L. euchæta Giesbr.
L. lævidentata (Brady).
L. maduræ A. Scott.
L. minuta Giesbr.
L. pavo Giesbr.
L. pectinata Thompson and A. Scott (? = *L. bipinnata* Tanaka).
**Ivellopsis elephas* Brady.
**Pontella alata* A. Scott.
**P. cerami* A. Scott.
**P. chierchiæ* Giesbr.
**P. cristata* Krämer.
P. denticauda A. Scott.
**P. forficula* A. Scott.
**P. kieferi* Pesta.
**P. longipedata* Sato.
**P. novæ-zelandiæ* Farran.
P. whiteleggei Krämer.
Pontellopsis armata (Giesbr.).
P. macronyx A. Scott.
P. perspicax (Dana).
**P. pexa* A. Scott.
P. strenua (Dana).
P. tenuicauda (Giesbr.).
P. villosa Brady.
Calanopia aurivillii Cleve.
C. elliptica (Dana).
C. herdmani A. Scott.
C. minor A. Scott.
C. thompsoni A. Scott.
**Acartia* (*Odontacartia*) *australis* Farran.
A. (*O.*) *amboinensis* Carl.
A. (*O.*) *bispinosa* Carl.
A. (*O.*) *erythræa* Giesbr.
A. (*O.*) *pacifica* Steuer.
A. (*O.*) *spinicauda* Giesbr.
A. (*Acanthacartia*) *bifilosa* Giesbr.
A. (*Acartiura*) *ensifera* Brady (= *A. clausi* Giesbr.).
(*)*A.* (*A.*) *simplex* Sars (? = *A. clausi* Giesbr.).
Tortanus barbatus (Brady).
T. gracilis (Brady).

T. (*Atortus*) *brevipes* A. Scott.
**T.* (*A.*) *murrayi* A. Scott.
Oithona fallax Farran.
O. minuta T. Scott.
O. rigida Giesbr.
O. robusta Giesbr.
O. simplex Farran.
O. tenuis Rosendorn.
Oncæa clevei Früchtl.
Corycæus (*Ditrichocorycæus*) *asiaticus* F. Dahl.†
C. (*D.*) *dubius* Farran.
C. (*D.*) *erythræus* Cleve.
**C.* (*D.*) *farrani* Früchtl.
C. (*D.*) *inuncus* Farran.
C. (*D.*) *lubbocki* Giesbr.
C. (*D.*) *minimus* F. Dahl.
C. (*D.*) *subtilis* M. Dahl.
Sapphirina intestinata Giesbr.
S. gastrica Giesbrecht.
S. lactens Giesbrecht.
S. sali Farran, (= *pseudolactens* Rosendorn).
Ectinosoma australe Sars (= *E. melaniceps* Boeck).
**Corissa parva* Farran.

Further investigations may reveal the presence of certain of these species in the eastern part of the Pacific Ocean, but it is equally possible that at least the majority of these forms have actually originated in the tropical and sub-tropical western and south-western region, and have not as yet been carried eastward and been able to survive in the south-eastern region of the Pacific Ocean. Of the species contained in the above list those that are marked with an asterisk have not, up to the present time, been recorded from any other region; one of these species may be a synonym and this I have indicated by putting the asterisk in brackets. Excluding this, we have 28 species that appear to be entirely local in their distribution and so may be regarded as endemic. In addition to these marine species certain others, belonging to marine genera, appear to have evolved in this western Pacific region and have invaded brackish- or even fresh-water; in all probability it is this invasion of brackish-water areas that has been responsible for the evolution of the new species. Such species are:

Pseudodiaptomus dauglishi Sewell,
Cyclopinodes pusilla (Sars),

which are brackish-water species, and

Sinocalanus mystrophorus Burckhardt,
S. solstitialis Brehm,
S. tenellus (Kikuchi),
Limnocalanus sinensis Poppe,

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† M. Dahl (1912, p. 77) has suggested that *Corycæus asiaticus* F. Dahl may be a synonym of *Corycæus auklandicus* Krämer, described from New Zealand.

Pseudodiaptomus forbesi Poppe and Mrazek,
P. inopinus Burckhardt,
P. japonicus Kikuchi, (? = *P. inopinus*),
P. nostradamus Brehm,
P. poppei Stingelin,
P. smithi Wright,
P. trihamatus Wright,
Limnoithona sinensis Burckhardt,

all of which are inhabitants of fresh-water and have not up to the present time been recorded from any other region.

In past geological ages there have been very considerable changes in the character of the East Indies and the Malayan region. In late Cretaceous and early Tertiary times the connection between the Pacific and Indian Oceans appears to have been considerably more extensive than it is at the present day. With the upheaval of the Himalayan mountain system in Tertiary times a series of ridges arose forming the Malayan and the Andaman-Sumatra-Timor arcs. This process continued throughout Eocene and Miocene times, and Kuenen (1935, p. 106) remarks, " Nearly all the islands in the eastern part of the Indies show signs of recent elevation, so that we can hardly be wrong in supposing that in a comparatively recent period the island arcs were hardly anywhere above sea-level. . . . This means that taken as a whole the amount of relief is increasing, and that therefore the Archipelago consisted of smaller and fewer islands or was even almost entirely submarine at the close of the Tertiary period." During the Pleistocene Glacial epoch there occurred a general lowering of the sea-level in the tropical belt that brought about the appearance of two great land masses, the Sunda and Sahul shelves, between which the only connection between the Pacific and Indian Oceans ran in a north-east to south-west direction past the island of Celebes. Still later with the rise of sea-level, consequent on the melting of the ice and continued orogenetic movement the present conditions arose and numerous connections were formed between the two regions. Throughout the whole period it seems probable that the surface interchange between the two oceans was reversed twice each year with the alternating north-east and south-west monsoons. Such an interchange must have brought about an admixture of Indian and Pacific plankton, and hence such species as are known to occur in both the south-west Pacific and the Indian regions may have originated in either area and have subsequently been swept in either direction; thus the number of indigenous species from the south-west Pacific, as given above, may be too high, for some, and possibly all, those that are known from these two areas but have not been found further to the east may have originated in Indian waters and subsequently have been carried eastward to the Pacific area or, *vice versa*, they may have arisen in the Pacific and have been swept westward.

Another and less direct route by which species may have been swept from the south-west Pacific region into the Indian Ocean is by means of the east Australian current and its continuation along the south coast of Australia during the months of January to May each year. Schott (1935, pl. xxix) shows that in February and March a warm branch of the east Australian current sweeps westward either between Australia and Tasmania or to the south of this latter island, and then flows on along the whole of the south coast of Australia, finally turning northwards up the west coast to join the south Equatorial current in the Indian Ocean. In the month of February, Schott (1935, pl. xx) indicates that the temperature of the water along the south side of Australia lies between 15° and 20° C. The work of Dakin and Colefax (1933 and 1940) and Nicholls (1944) has given us records of a number of species from the south-east and south coasts of Australia; these are as follows:

Calanus finmarchicus (Gunn.).
C. tenuicornis Dana.
Calanoides brevicornis (Claus).
Nannocalanus minor (Claus).
Canthocalanus pauper (Giesbr.).
Undinula darwini (Lubb.).
U. vulgaris (Dana).
Eucalanus crassus Giesbr.
E. monachus Giesbr.
Rhincalanus cornutus Dana.
Mecynocera clausi Thompson.
Paracalanus aculeatus Giesbr.
P. parvus (Claus).
Acrocalanus gibber Giesbr.
A. gracilis Giesbr.
Calocalanus plumulosus (Claus).
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
Ctenocalanus vanus Giesbr.
Euchæta concinna Dana.
E. marina (Prestand.).
Scolecithrix danæ (Lubb.).
Centropages bradyi Wheeler.
C. calaninus (Dana).
C. chierchiæ Giesbr.
C. furcatus (Dana).
C. gracilis (Dana).
C. kröyeri Giesbr.
C. orsinii Giesbr.
C. violaceus Brady.
Gladioferens brevicornis Henry.
Pseudodiaptomus hickmani Sewell, var.
Temora discaudata Giesbr.
T. stylifera (Dana).
T. turbinata (Dana).
Lucicutia flavicornis Claus.
Pseudocyclops australis Nicholls.
Candacia æthiopica Dana.
C. bipinnata Giesbr.
C. catula Giesbr.
C. pachydactyla Dana.

C. pectinata Brady.
C. truncata Dana.
Calanopia elliptica (Dana).
C. thompsoni A. Scott.
Labidocera acuta (Dana).
L. acutifrons (Dana).
L. brunescens (Czern.).*
L. caudata Nicholls.
L. cervi Krämer.
L. detruncata (Dana).
L. kröyeri Brady.
L. minuta Giesbr.
Pontella cristata Krämer.
P. novæ-zelandiæ Farran.
P. securifer Brady.
Pontellopsis regalis (Dana).
P. krämeri (Giesbr.).
Pontellina plumata Dana.
Acartia clausi Giesbr.
A. centrura Giesbr.
A. danæ Giesbr.
Tortanus barbatus Brady.
Oithona atlantica Farran.
O. brevicornis Giesbr.
O. nana Giesbr.
O. oculata Farran.
O. plumifera Baird.
O. setigera Dana.
O. similis Claus.
O. tenuis Rosendorn.
Oncæa conifer Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. venusta Philippi.
Corycæus africanus F. Dahl.
C. agilis Dana.
C. andrewesi Farran.
C. anglicus Lubb.†
C. catus F. Dahl.
C. clausi F. Dahl.
C. crassiusculus Dana.
C. furcifer Claus.

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* I am inclined to doubt the correctness of this identification. *Labidocera brunescens* is a Mediterranean and Black Sea species, and though Dakin and Colefax state that it has been taken in the Indian Ocean, I have not been able to confirm this.

† I doubt the correctness of this identification.

C. giesbrechti F. Dahl.
C. latus Dana.
C. lautus Dana.
C. lubbocki Dana.
C. longistylis Dana.
C. pacificus F. Dahl.
C. speciosus Dana.
C. tenuis Giesbr.
C. vitreus Dana.
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *concinnus* (Dana).
C. (*C.*) *gibbulus* Giesbr.
C. (*C.*) *rostratus* (Claus).
Sapphirina angusta Dana.
S. auronitens Claus—*sinuicauda* Brady.
S. gastrica Giesbr.
S. intestinata Giesbr.
S. nigromaculata Claus.
S. opalina Dana—*darwini* Haeckel.
S. ovatolanceolata Dana—*gemma* Dana.
S. scarlata Giesbr.
S. stellata Giesbr.
Copilia mirabilis Claus.
C. quadrata (Dana).
C. vitrea (Haeckel).
Microsetella rosea Dana.
Euterpina acutifrons (Dana).
Macrosetella gracilis (Dana).

The great majority of these species were taken during the months January–May; during the succeeding months of July–September there is a marked decrease in the number of species recorded, but a few were taken that have not been recorded in the earlier months, namely:

Rhincalanus cornutus Dana.
Calanoides patagoniensis Brady.
Scolecithrix danæ (Lubb.).
Centropages violaceus (Claus).
Corycaeus (*Onychocorycæus*) *giesbrechti* F. Dahl.
Sapphirina opalina Dana.

During the months August–September the south Australian coast as far east as Tasmania is bathed by water that is coming out of the Indian Ocean and is flowing eastwards; and it is interesting to note that all these last species are known to be inhabitants of that Ocean. To the above list of species, that have in all probability been carried to the South Australian coast from the Indian Ocean, should be added *Corycæus* (*Ditrichocorycæus*) *africanus* F. Dahl, which occurs in this area from January to August, and *Pseudodiap-*

tomus hickmani Sewell var. taken in the spring. Later in the year, in October–December, the number of recorded species falls still lower to 15, and among these are—

Calanoides brevicornis (Lubb.),
Centropages chierchiæ Giesbr.,
Labidocera detruncata (Dana),
Corycæus (*Corycella*) *rostrata* (Claus),
Sapphirina angusta Dana,

all of which have been recorded from the Indian Ocean, though *Centropages chierchiæ* Giesbr. is essentially an Atlantic species and has only been taken in the south-western area of the Indian Ocean, to which it may have been carried, as I have suggested later (*vide infra*, p. 432), by the deep current of Atlantic intermediate water that flows eastward past the Cape of Good Hope and on across the southern part of the Indian Ocean to the Pacific.

Around the coasts of the Tasman Sea and along the south coast of Australia there has been, in the past, a marked invasion of fresh-water. This has been the case particularly in the Centropagidæ, in which two genera, *Gladioferens* and *Brunella*, are represented by a number of species. In the genus *Gladioferens* Henry we have records of the following seven species :

G. inermis Nicholls from salt- or brackish-water in South Australia.
G. pectinatus (Brady) from salt- or brackish-water in New Zealand.
G. imparipes Thomson from salt- or brackish-water in Western Australia.
G. brevicornis Henry from salt- or fresh-water in New South Wales.
G. spinosus Henry from fresh-water in New South Wales.
G. gracilis Kiefer from fresh-water in New Zealand.
G. subsalaria Percival from fresh-water in New Zealand.

The genus *Brunella* Smith appears, with a single exception, to be confined entirely to fresh-water, and the following species have been recorded :

B. steeli Henry from fresh-water in New Zealand.
B. ampulla Searle ,, ,, Victoria, Australia.
B. expansa Sars ,, ,, ,, ,,
B. longicornis Searle ,, ,, ,, ,,
B. australis Searle ,, ,, ,, ,,
B. viridis Searle ,, ,, ,, ,,
B. salina Nicholls from a salt lake, South Australia.
B. tasmanica Smith from fresh water in Tasmania.

Nicholls (1944, p. 5), in a footnote, states that two other species in this genus have been recorded from Western Australia ; I have been unable to see this paper.* The distribution of these species taken in conjunction with the distribution of such marine species as *Labidocera cervi* Krämer points to a transfer of species from the New Zealand region round the Tasman Sea and along the east coast of Australia, by the East Australian Current, and then westward along the south coast of Australia at some earlier period.

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* Fairbridge, W. S., 1944, ‘Journ. Roy. Soc. West. Aust., xxix.

A number of species that seem, so far as the present evidence goes, to have had their origin in the central and western Pacific region, have been recorded from regions lying to the west; up to the present time 31 of these species have been taken in the Indian Ocean, but have not, as yet, been recorded from either the Red Sea or the Atlantic Ocean, namely:

Paracalanus dubia Sewell (=*P. crassirostris* F. Dahl, var. *sewelli* Früchtl).
P. denudatus Sewell.
Acrocalanus gardineri Wolfenden.
A. inermis Sewell.
Clausocalanus farrani Sewell.
Euchæta consimilis Farran.
E. wolfendeni A. Scott.
Scolecithricella nicobarica Sewell.
Pseudodiaptomus aurivillii Cleve.
P. mertoni Früchtl.
Metacalanus aurivillii Cleve.
Candacia discaudata A. Scott.
Labidocera bataviæ A. Scott.
L. euchæta Giesbr.
L. lævidentata (Brady).
L. maduræ A. Scott.
Pontella denticauda A. Scott.
Pontellopsis armata (Giesbr.).
P. macronyx A. Scott.
Calanopia aurivillii Cleve.
C. herdmani A. Scott.
C. thompsoni A. Scott.
Acartia (*Odontacartia*) *amboinensis* Carl.
A. (*O.*) *bispinosa* Carl.
A. (*O.*) *pacifica* Steuer.
A. (*O.*) *spinicauda* Giesbr.
Oithona oculata Farran.
Oncæa clevei Früchtl.
? *Corycæus dubius* Farran (= *erythræus* Cleve).
Sapphirina intestinata Giesbr.
S. sali Farran (= *pseudolactens* Rosendorn).

Twelve species have been able to pass through the Indian Ocean and have been recorded from the Red Sea, but have not reached the Gulf of Suez, namely:

Euchæta concinna Dana.
Centropages elongatus Giesbr.
C. orsinii Giesbr.
C. violaceus (Claus).
Candacia bradyi Wheeler.
C. longimana Dana.
Pontellopsis krämeri Giesbr.

Calanopia minor A. Scott.
Tortanus barbatus (Brady).
Oithona minuta T. Scott.
O. rigida Giesbr.
Corycæus lubbocki Giesbr.

And finally 9 species have reached the Gulf of Suez and the Suez Canal, to wit:

Paracalanus crassirostris F. Dahl.
Labidocera minuta Giesbr.
L. pavo Giesbr.
Calanopia elliptica (Dana).
Acartia (*Odontacartia*) *erythræa* Giesbr.
Tortanus gracilis (Brady).
Oithona simplex Farran.
Corycæus (*Ditrichocorycæus*) *asiaticus* F. Dahl.
C. (*D.*) *erythræus* Cleve.

A number of species that appear to have had their origin in the west Pacific region inasmuch as they have never, up to the present time, been recorded from waters lying further to the east, have been taken in the Atlantic Ocean, and there seems little doubt that many, if not most, of these have been swept in a westerly direction past the Cape of Good Hope in a branch of the Agulhas Current. These species are as follows:

Paracalanus crassirostris F. Dahl.
Calocalanus contractus Farran.
Clausocalanus paululus Farran.
C. pergens Farran.
Euchæta concinna Dana.
E. pubera Sars.
Scolecithricella dentata (Giesbr.).
Centropages kröyeri Giesbr.
C. violaceus Brady.
Temora longicornis (O. F. M.).
T. turbinata (Dana).
Temoropia mayumbæensis (T. Scott).
Candacia longimana Dana.
C. tenuimana Giesbr.
C. varicans Giesbr.
Labidocera kröyeri (Brady).
L. nerii (Kröyer).
Pontellopsis perspicax (Dana).
P. villosa Brady.
Oithona minuta T. Scott.
O. robusta Giesbr.
O. simplex Farran.
O. tenuis Rosendorn.
Corycæus (*Corycæus*) *clausi* F. Dahl.
Ectinosoma melaniceps Boeck (= *E. australe* Sars).

Six of the above species, namely, *Clausocalanus paululus*, *C. pergens*, *Euchæta pubera*, *Temoropia mayumbæensis*, *Labidocera nerii* and *Corycæus* (*Corycæus*) *clausi* F. Dahl, have not as yet been recorded from the Indian Ocean, although they are known from both the west Pacific and the Atlantic; it seems probable that further research will reveal their presence in the intermediate region. To these five species may be added *Corycaeus* (*Agetes*) *limbatus* Brady that is now known from the east and west Pacific regions and from the North Atlantic and Mediterranean regions, but is unknown from the Indian Ocean; and the doubtful species *Eucalanus setiger* Brady, originally recorded from the west Pacific and later by T. Scott from the Gulf of Guinea, and by Thompson from the North Atlantic and the Mediterranean regions. Of the above species a few exhibit a very considerable range of tolerance to reduced salinity, and are frequently, if not invariably, taken in brackish water, such as *Paracalanus crassirostris* F. Dahl and *Oithona simplex* Farran, and the same may be said of the east Pacific species *Oithona brevicornis* Giesbr.; such forms may have made their way westward along the inshore littoral margin by active migration, but they also appear to be capable of withstanding a wide range of salinity, and thus of surviving long passages across the open ocean; on the other hand, if they were in existence in remote Tertiary times, it is possible that they reached their western habitat through the Tethys Sea, and this is most likely in the case of *Paracalanus crassirostris* F. Dahl, which has already developed local races in Indian waters and on both sides of the Atlantic Ocean (*vide* Früchtl, 1924, p. 36).

It is possible that the same explanation holds good in the case of *Temoropia mayumbæensis* (T. Scott); this species has been recorded from the south-west Pacific region, the Gulf of Suez, the Gulf of Guinea and the British Isles. The occurrence in the Gulf of Suez, however, appears open to doubt; the record is by Thompson and A. Scott (1903), but the method of collecting was that previously adopted by Herdman of tying a muslin or silk bag to a bath-room tap and so filtering the water as it flowed out of the ship's tanks; but this gives no indication as to the position of the ship when the water was pumped into the tanks from the sea. This must have been previous to the appearance of the organism in the tap-water, and may have been very considerably earlier. The only two occasions on which *Temoropia mayumbæensis* were taken were during the passage of the steamer outward bound through the Gulf of Suez, and it is possible that the water which contained the specimens was pumped in from the eastern part of the Mediterranean Sea. Assuming this to have been the case, the distribution of this species then becomes confined to the south-west Pacific, the Mediterranean Sea and the Gulf of Guinea, all three localities being either close to the entrance or exit or actually part of the ancient Tethys Sea. Two of the above species, namely, *Euchæta concinna* Dana and *Oithona tenuis* Rosendorn, have been unable to get any further than the tropical region of the Atlantic Ocean, but the great majority have been swept into the north temperate region, and their further distribution in that region will be dealt with later (*vide infra*, p. 459).

Turning now to the Indian Ocean, as many as 270 species have been recorded from this region or its offshoots the Persian Gulf and the Red Sea (*vide* Giesbrecht (1896), A. Scott (1902), Thompson (1900), Thompson and A. Scott (1903), Cleve (1901, 1903, 1904), Wolfenden (1906), Stebbing (1910), Pesta (1913), Farran (1911), Brady (1914, 1915), Sewell (1912, 1914, 1919, 1924, 1929, 1932), Gurney (1927) and Menon (1931)). A large number of species appear to have had their origin in this region, inasmuch as they have never, up to the present time, been recorded from further east. I have already pointed out that there is a continuous connection through the Malay Archipelago and the Strait of Malacca between the Pacific and the Indian Oceans, and that it is thus difficult to draw a line between the two regions, but for convenience I have taken the eastern boundary of the Indian Ocean in the Strait of Malacca to be long. 100° E. Fifty-six species have so far not been recorded outside the Indian Ocean, namely :

Calanoides natalis Brady.†
Paracalanus nudus Sewell.
P. serratipes Sewell.
Euchæta affinis Cleve.
E. murrayi Sewell.
Macandrewella scotti Sewell.
Scolecithricella pearsoni Sewell.
Centropages alcocki Sewell.
C. dorsispinatus Thompson and A. Scott (= *notoceras* Cleve).
C. tenuiremis Thompson and A. Scott (= *arabicus* Cleve).
C. trispinosus Sewell.
C. tenuicornis Brady.
**Pseudodiaptomus annandalei* Sewell.
**P. binghami* Sewell.
P. burckhardti Sewell.
P. dubius Kiefer.
**P. lobipes* Gurney.
P. masoni Sewell.
**P. tollingeræ* Sewell.‡
**Isias tropica* Sewell.
Pseudocyclops simplex Sewell.
Labidocera chubbi Brady.
L. inermis Brady.
**L. gangetica* Sewell.
L. similis Cleve.
**Pontella andersoni* Sewell.
P. investigatoris Sewell.
P. natalis Brady.
P. spinipes Giesbr.
Pontellopsis herdmani Thompson and A. Scott.
P. scotti Sewell.
**Acartia* (*Acartiella*) *gravelyi* Sewell.
**A.* (*A.*) *kempi* Sewell.
**A.* (*A.*) *major* Sewell.
**A.* (*A.*) *minor* Sewell.
**A.* (*A.*) *sewelli* Steuer.
**A.* (*A.*) *tortaniformis* Sewell.
**A.* (*Euacartia*) *southwelli* Sewell.

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† This species is of doubtful validity.

‡ I originally named this species *tollingeri* ; it has since been pointed out that the correct name should be *tollingeræ*.

*_A._ (_Acanthacartia_) _chilkaensis_ Sewell.
_A._ (_A._) _pietschmani_ Pesta.
A. longisetosa Brady.†
A. nana Brady.†
Tortanus (_Atortus_) _recticauda_ Giesbr.
_T._ (_A._) _tropicus_ Sewell.
Oithona decipiens Farran.
*_O. dissimilis_ Lindberg.
O. erythrops Brady.†
O. hamata Rosendorn.
*_O. horai_ Sewell.
Dioithona alia Kiefer.
*_D. indo-gallica_ Lindberg.
Paroithona pula Farran.
Oithonopsis farrani Brady.†
Corycæus latissimus Brady.
C. latus Dana.
Corycella brevis Farran.
Sapphirina serrata Brady.

Many of the above species have been taken in brackish-water, and these I have indicated by an asterisk, while one species, _Pseudodiaptomus lobipes_, is an inhabitant of fresh-water. The head of the Bay of Bengal appears to be a region where this penetration from the sea into brackish-water has been particularly active, and this doubtless is associated with the presence in this region of the estuaries of several large rivers, such as the Irrawaddi River, that empties through an extensive delta into the northern end of the Andaman Sea, the Brahmaputra and Ganges rivers that empty through a common delta into the head of the Bay of Bengal, and the Mahanaddi River that has its own delta, connected with the Chilka Lake, at the northern end of the east coast of India, while opening on the east coast of India are the estuaries of the Godaveri and Kistna rivers.

In consequence of the comparatively free interchange that takes place between the eastern part of the Indian Ocean and the Malayan region of the western Pacific Ocean it is probable that some, and perhaps many, of the above species will ultimately be recorded from this latter area; but from a study of the distribution within the Indian Ocean of those species that are known to occur also in the Malayan region it seems probable that the main trend of dispersal has been from east to west rather than _vice versa_. In the following table I have given the number of surface-living Calanoida that have been taken in the Malay Archipelago and have also been recorded from the Indian Ocean; and it is clear that as we pass westward there is a gradual falling off in numbers, and a similar

Region in which species have probably been evolved.	Number of species that have been taken in —				
	Malay Archipelago.	South Burma, Andaman and Nicobar Islands.	Ceylon Pearl Banks.	Arabian Sea.	Red Sea.
Malay Archipelago	117	85	71	67	52
S. Burma coast and Andaman and Nicobar Islands	..	16	9	4	4
Ceylon Pearl Banks	..	..	6	3	1

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† These species are of doubtful validity.

reduction is seen in the number of species that appear to have been evolved in the different regions of the Indian Ocean itself.

It is somewhat surprising that so few of the species that appear to have originated in the Indian Ocean have been able to penetrate into the Red Sea. Three species have been taken in the Red Sea itself, namely,

Macandrewella chelipes (Giesbrecht),
Oithona fallax Farran,
Sapphirina maculosa Giesbr.,

and two others have been able to pass through the Red Sea and have been recorded from the Gulf of Suez and the Suez Canal, namely,

Pseudodiaptomus salinus Giesbr,.
Acartia (*Odontacartia*) *centrura* Giesbr.

A number of these species that have not, up to the present time, been recorded from further east than the Indian Ocean are also known to occur in the Atlantic Ocean, and have therefore been able to survive the passage in one direction or another round the Cape of Good Hope. Some of these species seem definitely to be Indian and so have passed westwards, doubtless in the branch of the Agulhas Current, to which attention has already been drawn. These species are the following:

Paracalanus nanus Sars.
Pseudodiaptomus serricaudatus T. Scott.
Pseudocyclops obtusatus Grady and Robertson.
Candacia inermis Cleve (= *obtusa* Sars, *rotundata* Wolf.).
Pontella spinipes Giesbr.
Acartia centrura Giesbr.
A. plumosa T. Scott.
Oithona fallax Farran.
O. hamata Rosendorn.
O. pseudofrigida Rosendorn.
O. vivida Farran.
Paroithona parvula Farran.
Corycæus (*Ditrichocorycæus*) *minimus* F. Dahl s.sp.*
C. (*Onychocorycæus*) *latus* Dana (= *indicus* M. Dahl).
Sapphirina maculosa Giesbr.
Ectinosoma normani T. and A. Scott.

In addition to these, a number of species, that seem to be normal inhabitants of the Atlantic Ocean or its offshoot the Mediterranean Sea, have occasionally been reported from the Indian Ocean. Such species are—

Calanus finmarchicus Gunn.,
Ctenocalanus vanus Giesbr.,
Centropages typicus Kröyer,
C. hamatus (Lillj.),

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* M. Dahl (1912, p. 128) maintains that this species is confined to the Atlantic Ocean.

Euchæta hebes Giesbr.,
Labidocera nerii Krämer,
Pontella atlantica (M. E.),
P. mediterranea (Claus),
Anomalocera patersoni Templ.,
Parapontella brevicornis (Lubb.),

and perhaps to these should be added *Centropages chierchiæ* Giesbr. It is possible that the records of some of these species in the Indian Ocean are due either to incorrect record of their habitat or to faulty identification. A single specimen of *Calanus finmarchicus* Gunn. was taken by the " John Murray " Expedition in the Arabian Sea, and *Anomalocera patersoni* Templ. has been recorded by Thompson (1900) from the region of the Agulhas Current off the east coast of South Africa ; but the record of occurrence of *Anomalocera patersoni* Templ., *Pontella mediterranea* and *Parapontella brevicornis* (Lubb.) from the Maldive and Laccadive Archipelagos by Wolfenden (1906) could be explained by accidental mixing of collections from this region and the Atlantic Ocean. On the other hand, it is possible that these stray individuals have been carried eastward from the Atlantic Ocean into the Indian Ocean by a deep current of Atlantic Intermediate water, which, as I shall show later (*vide infra*, p. 522), seems to be responsible for the transference eastward of many deep-dwelling species from one ocean to another ; such a transference would seem to be the more probable explanation in the case of *Calanus finmarchicus* Gunn. and *Anomalocera patersoni* Templ., both of which are known to live in the Atlantic Ocean as deep as 750 m., at which depth they would be inhabitants of the north Atlantic intermediate water. *Pontella atlantica* (M. E.) may have been carried eastward in the same deep current ; this species has been recorded from the Indian Ocean, Mori (1935) records it off Japan, and Wilson (1942) reports its presence in both north and south regions of the east Pacific area. Its appearance in this latter region may, if we accept the view that the species was in existence in the Tertiary epoch and has remained unchanged ever since, be ascribed to the presence at that time of a direct connection between the Atlantic and Pacific Oceans across what is now Central America. Farran (1926) has suggested that *Centropages chierchiæ* Giesbr. is a Mediterranean species, and that it has been swept out in the outflowing deep current into the Atlantic Ocean and then carried northwards into the Bay of Biscay ; it has now been established that this outflowing current of Mediterranean water flows westward and joins the North Atlantic intermediate Current, a branch of which flows eastward past the Cape of Good Hope into the southern part of the Indian Ocean, and can even be traced as far as the south-west region of the Pacific. It seems possible that the occurrence of examples of the Atlantic variety of *Rhincalanus cornutus* at Stas. 135 and 145 in the " Valdivia " collections (*vide* Schmaus and Lahnhofer, 1927), both of which lie to the south and somewhat to the east of the Cape of Good Hope, may be due to the same deep current, for the depth at which these examples were taken was 1500 m. The occurrence of *Labidocera brunescens* (Czern.) off the coast of New South Wales, reported by Dakin and Colefax (1933), may, if confirmed, be attributed to the same deep water movement.

Our knowledge of the Copepod fauna of the Red Sea is due to the work of Giesbrecht (1892, 1897), Steuer (1898), Thompson (1900), A. Scott (1902), Thompson and A. Scott (1903), Cleve (1903) and Schiacchitano (1930).

I have been able to collate references to 111 species that have been taken in this enclosed area :

Nannocalanus minor (Claus).
Canthocalanus pauper (Giesbr.).
Undinula darwini (Lubb.).
U. vulgaris (Dana).
Eucalanus crassus Giesbr.
E. pileatus Giesbr.
E. subcrassus Giesbr.
E. subtenuis Giesbr.
Rhincalanus cornutus Dana.
R. nasutus Giesbr.
Mecynocera clausi Thompson.
Paracalanus aculeatus Giesbr.
P. crassirostris F. Dahl.
P. parvus (Claus).
Acrocalanus gibber Giesbr.
A. gracilis Giesbr.
A. longicornis Giesbr.
A. monachus Giesbr.
Calocalanus pavo (Dana).
C. plumulosus (Claus).
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
Euchæta concinna Dana.
E. marina (Prestand.).
Macandrewella chelipes (T. Scott).
Centropages calaninus (Dana).
C. elongatus Giesbr.
C. furcatus (Dana).
C. gracilis (Dana).
C. orsinii Giesbr.
C. violaceus (Claus).
Temora discaudata Giesbr.
T. stylifera (Dana).
T. turbinata (Dana).
Pseudodiaptomus salinus (Giesbr.).
Lucicutia flavicornis (Claus).
Candacia æthiopica Dana.
C. bispinosa Claus.
C. bradyi Wheeler.
C. catula Giesbr.
C. curta Dana.
C. longimana Claus.
C. simplex Giesbr.

C. truncata Dana.
Calanopia elliptica (Dana).
C. minor A. Scott.
Labidocera acuta (Dana).
L. minuta Giesbr.
L. orsinii Giesbr.
L. pavo Giesbr.
Pontella fera Dana.
Pontellopsis krameri (Giesbr.).
Pontellina plumata Dana.
Acartia (*Odontacartia*) *centrura* Giesbr.
A. (*Acartiura*) *clausi* Giesbr.
A. (*Odontacartia*) *erythræa* Giesbr.
A. (*Planktacartia*) *negligens* Dana.
Tortanus (*Tortanus*) *barbatus* Brady (= *denticulatus* Giesbr.).
T. (*T.*) *forcipatus* (Giesbr.).
T. (*T.*) *gracilis* (Brady).
T. (*Atortus*) *recticauda* Giesbr.
Oithona fallax Farran.
O. linearis Giesbr. (= *setigera* Dana).
O. nana Giesbr.
O. plumifera Baird.
O. rigida Giesbr.
O. robusta Giesbr.
O. setigera Dana.
O. similis Claus.
O. simplex Farran.
Oncæa conifera Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. minuta Giesbr.
O. notopus Giesbr.
O. venusta Philippi.
Lubbockia aculeata Giesbr.
L. squillimana Claus.
Corycæus (*Corycæus*) *crassiusculus* Dana.
C. (*C.*) *speciosus* Dana.
C. (*Monocorycæus*) *robustus* Giesbr.
C. (*Agetes*) *flaccus* Giesbr.
C. (*A.*) *typicus* Kröyer.
C. (*Urocorycæus*) *longistylis* Dana.
C. (*Ditrichocorycæus*) *asiaticus* F. Dahl.
C. (*D.*) *erythræus* Cleve.
C. (*D.*) *lubbocki* Giesbr.
C. (*Onychocorycæus*) *agilis* Dana (= *gracilicaudatus* Giesbr.).
C. (*O.*) *catus* F. Dahl.

C. (*O.*) *obtusus* Dana (= *catus* F. Dahl).
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *gibbulus* Giesbr.
C. (*C.*) *rostratus* Claus.
Sapphirina auronitens Claus—*sinuicauda* Brady.
S. bicuspidata Giesbr.
S. gastrica Giesbr.
S. lactens Giesbr.
S. maculosa Giesbr.
S. metallina Dana.
S. nigromaculata Claus.
S. opalina Dana—*darwini* Haeckel.
S. ovatolanceolata Dana—*gemma* Dana.
S. scarlata Giesbr.
Copilia mirabilis Dana.
Ectinosoma melaniceps Boeck.
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
Macrosetella gracilis (Dana).
Clytemnestra rostrata (Brady).
C. scutellata Dana.

Farran (1911) has given *Calanus finmarchicus* (Gunn.) as occurring in the Red Sea. I was unable to trace any reference to the occurrence of this species in this locality, and on referring the matter to Mr. Farran he has kindly written to say that it must be a clerical error, committed when tabulating one of the Red Sea lists, and he has asked me to correct this.

Two of the above species appear to be "endemic" in this area, namely *Labidocera orsinii* Giesbr. and *Tortanus* (*Atortus*) *recticauda* Giesbr.; all the other species are known to be inhabitants of the Indo-Pacific region, and a study of the individual species reveals that 107 are known to inhabit this region, and of these as many as 78 have been recorded from the east Pacific area, 23 from the west, but not from the east, Pacific region, and 6 have not been recorded from east of the Indian Ocean. In the following table I have given the total number of species that appear to be indigenous in each of the three areas, and the number that have been recorded from the Red Sea:

Region.	Total number of indigenous species.	Number taken in the Red Sea.	Percentage.
East Pacific region	179	78	44%
West Pacific region	109	23	21%
Indian Ocean	72	6	8%

In comparison with the Indian Ocean, from which we have records of some 270 species, the Copepod fauna of the Red Sea is distinctly poor. At the present day the only entrance for planktonic organisms into the Red Sea appears to be through the Gulf of Aden and the

Strait of Bab-el-Mandeb, for, as Gurney (1927, p. 141) has pointed out, the Copepoda of the Suez Canal afford " no evidence of a southward migration through the Canal," and Munro Fox (1926, p. 39) has also pointed out that " the fact that the majority of the plants present in the canal waters are derived from the Red Sea affords additional evidence that the similar invasion of the canal by erythræan species of sessile animals is conditioned by currents, transporting spores and larvæ from the south to the north." Most of the collections that have been made in the Red Sea were taken in different months of the year, and it is very interesting to note the differences in the various collections. The number of species recorded in the different months are as follows:

Month.	Number of species.
January	73
March	42
April	40
June	37
July–August	29
October	38

Thompson (1939) has shown that " the exchange of water over the sill between the Red Sea and the Gulf of Aden is fundamentally different in the winter and summer months. In the winter, from October to April, there are but two masses of water moving over the 'sill', a very warm surface layer entering the Red Sea from the Gulf of Aden, and a deep outflow of very saline water passing out from the Red Sea. In the summer time there are three bodies of water moving over the 'sill', a wind-driven surface mass of high temperature water flowing out of the Red Sea into the Gulf of Aden, a bottom outflow of very saline water from the Red Sea into the Gulf, and an intermediate low salinity, low temperature inflow from the Gulf of Aden into the Red Sea." It seems probable that the monthly differences in the number of species can be correlated with the in-flowing and out-flowing surface currents; at the commencement of the winter season in October the number of species is low, 38, but as the current sets in and flows into the Red Sea it will carry with it numerous surface-living species from the Gulf of Aden, and the number of species taken in the Red Sea shows an increase to 73 in January. With the onset of the summer season (May to September) the surface water flows out of the Red Sea, and this may carry with it species that have been swept in during the winter months, so that the number of species taken in the Red Sea falls to a minimum of 29 in July–August. There are as many as 37 species which have only been recorded from the Red Sea during the winter season, namely:

Nannocalanus minor (Claus).
Undinula darwini (Lubb.).
Eucalanus subtenuis Giesbr.
Rhincalanus cornutus Dana.
Mecynocera clausi Thompson.
Paracalanus parvus (Claus).
Acrocalanus longicornis Giesbr.
Calocalanus plumulosus (Claus).

Clausocalanus arcuicornis (Dana).
Euchæta marina (Prestand.).
Centropages calaninus (Dana).
C. gracilis (Dana).
Candacia bradyi Wheeler.
Calanopia minor A. Scott.
Labidocera minuta Giesbr.
Pontella fera Dana.
Pontellina plumata Dana.
Acartia (*Odontacartia*) *centrura* Giesbr.
Tortanus (*Tortanus*) *gracilis* (Brady).
Oithona linearis Giesbr.
Oncæa conifera Giesbr.
O. media Giesbr.
O. mediterranea Claus.
Lubbockia aculeata Giesbr.
L. squillimana Claus.
Corycæus (*Corycæus*) *crassiusculus* Dana.
C. (*C.*) *elongatus* F. Dahl.*
C. (*C.*) *speciosus* Dana.
C. (*Monocorycæus*) *robustus* Giesbr.
C. (*Ditrichocorycæus*) *erythræus* Cleve.
C. (*D.*) *lubbocki* Giesbr.
C. (*Onychocorycæus*) *gracillicaudatus* Giesbr. (=*agilis* Dana).
C. (*O.*) *obtusus* Dana.
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *gibbulus* Giesbr.
Sapphirina auronitens Claus—*sinuicauda* Brady.
S. gastrica Giesbr.

Certain other species appear to be even more restricted in their appearance in the Red Sea and have been recorded only from the extreme south end; thus *Candacia bispinosa* Claus has been taken in this area in October and January, *Candacia simplex* Giesbr. in January and April, *Euchæta concinna* Dana only in October; and the following species only in the month of January:

Eucalanus crassus Giesbr.
E. pileatus Giesbr.
Acrocalanus monachus Giesbr.
Lucicutia flavicornis (Claus).
C. longimana Claus.
Candacia æthiopica Dana.
Sapphirina ovatolanceolata Dana—*gemma* Dana.
S. scarlata Giesbr.

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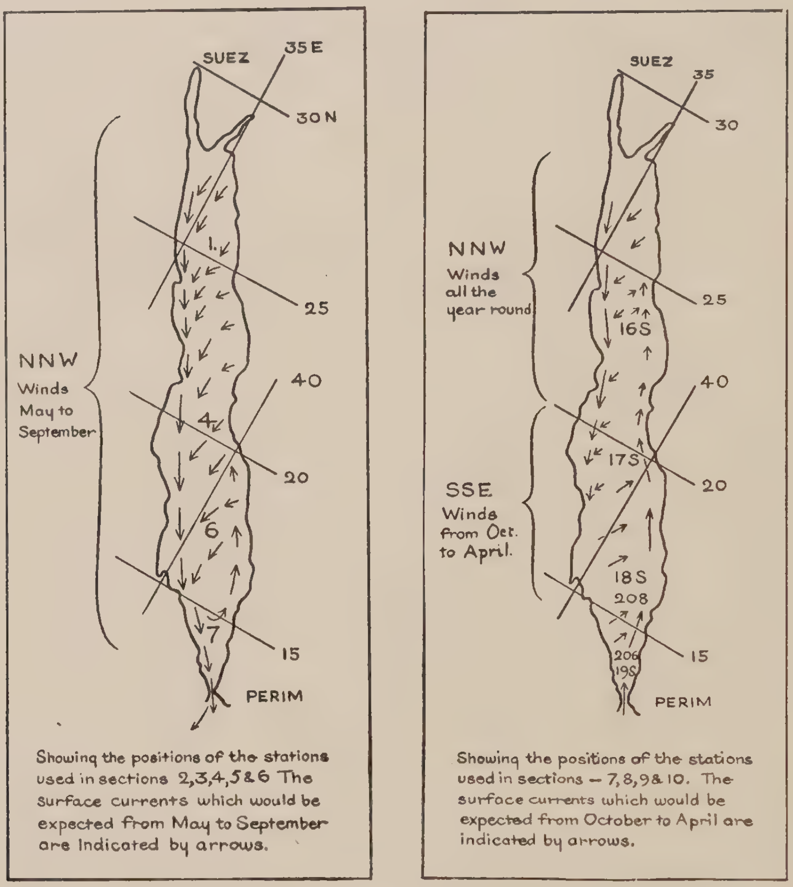
* *Corycæus elongatus* F. Dahl is almost certainly an immature stage of either *Corycæus crassiusculus* Dana or *C. speciosus* Dana.

A further factor that must have a profound influence on the distribution of the surface Copepoda within the limits of the Red Sea is the seasonal difference to be found in the general trend of the surface currents. Thompson (1939, p. 86) has given two charts showing the set of these currents during the summer (May to September) and winter (October to April) months, and he indicates that in the southern half of the Red Sea there is a counter-clockwise movement of the surface water, an inflowing current from the Gulf of Aden passing northwards on the east side and then turning round and passing southwards on the west side, but that the northern limit of the counter-clockwise movement lies in about lat. 20° N. during the summer months and in lat. 25° N. during the winter season, while to the north of this the whole of the surface water is moving southwards. This southward movement of the surface water must severely impede the passage of any epi-planktonic organisms northwards from the southern half of the Red Sea, and will tend to prevent altogether the spread of these organisms into the Gulf of Suez (*vide* Fig. 85).


SUEZ
35E
30N
25
40
20
15
PERIM
1.
4
6
7
NNW Winds May to September
Showing the positions of the stations used in sections 2,3,4,5 & 6 The surface currents which would be expected from May to September are Indicated by arrows.
SUEZ
35
30
25
40
20
15
PERIM
16S
17S
18S
208
206
19S
NNW Winds all the year round
SSE Winds from Oct. to April.
Showing the positions of the stations used in sections – 7,8,9 & 10. The surface currents which would be expected from October to April are indicated by arrows.

Text-fig. 85.

The absence, or only temporary occurrence, of so many species, which are widespread throughout the Indo-Pacific region, seems to indicate that conditions in the Red Sea are not favourable to their existence in that habitat. Stubbings (1939, p. 147) has pointed out that during the winter season the inflowing current into the Red Sea from the Gulf of Aden " carries the Pteropoda into the Red Sea, where they come into contact with the more saline and warmer Red Sea water, which proves fatal to them. Their shells sink down to form the deposit of Pteropod ooze met with on the north-west side of the " sill " ; and he gives the following table showing the rapid increase in the percentage of Pteropod shells in the deposit as one passes from the Gulf of Aden into the Red Sea:

Region.	Station.	Deposit.	Pteropod shells. % deposit.	Pteropod shells. % remains.
Gulf of Aden	12	cs. s. sh.	..	..
S.E. side of " sill "	9	r., s.	..	..
Top of " sill "	204	gn. m. Pt. sh.	0·4	1·5
N.W. side of " sill "	7	s., Pt. sh.	..	16·9
Ditto	206	Pt. oz.	8·0	60·5
,,	207	Pt. oz.	8·1	65·4

Clearly we have here a region of admixture of waters of different characteristics that is extremely fatal to the Pteropoda, and it would appear probable that it is equally fatal to a large number of Copepoda ; this would account for the absence in the Red Sea of more than half the number of species that are known to inhabit the Indian Ocean.

As we pass northwards to the region of the Gulf of Suez the copepod fauna gets even more scanty ; a study of the works of A. Scott (1902), Thompson and A. Scott (1903), Gurney (1927) and Nicholls (1944*b*) gives the following species whose presence in this area can be relied on :

Canthocalanus pauper (Giesbr.).
Undinula darwini (Lubb.).
Paracalanus aculeatus Giesbr.
P. crassirostris F. Dahl.
P. parvus Giesbr.
Acrocalanus gibber Giesbr.
Calocalanus pavo (Dana).
C. plumulosus (Claus).
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
Centropages calaninus (Dana).
C. furcatus Dana.
Pseudodiaptomus salinus (Giesbr.).
Temora discaudata Giesbr.
T. stylifera (Dana).
Pseudocyclops reductus Nicholls.
Lucicutia flavicornis (Claus).
Calanopia elliptica (Dana).
Labidocera acuta (Dana).
L. minuta Giesbr.
L. pavo Giesbr.
Acartia (Acartiura) clausi Giesbr.
A. (Odontacartia) centrura Giesbr.

A. (*O.*) *erythræa* Giesbr.
A. (*Planktacartia*) *negligens* Dana.
Tortanus (*Tortanus*) *gracilis* (Brady).
Oithona nana Giesbr. (southern form, *vide* Gurney, 1927, p. 159).
O. plumifera Baird.
O. similis Giesbr.
O. simplex Farran.
Oncæa media Giesbr.
O. minuta Giesbr.
O. venusta Philippi.
Lubbockia squillimana Claus.
Corycæus (*Corycæus*) *crassiusculus* Dana.
C. (*Ditrichocorycæus*) *asiaticus* F. Dahl.
C. (*D.*) *erythræus* Cleve.
C. (*Corycella*) *gibbulus* Giesbr.
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
Macrosetella graciltis (Dana).
Clytemnestra scutellata Dana.

A few other species have been recorded by Thompson and A. Scott (1903) and A. Scott (1902) from the Gulf of Suez or the neighbouring part of the Red Sea. Some of these may have reached this area from the Indian Ocean and the Red Sea, since they have been reported from these latter regions; these species are—

Oncæa mediterranea Claus.
O. notopus Giesbr.
Corycæus (*Corycæus*) *speciosus* Dana.
C. (*Onychocorycæus*) *obtusus* Dana.

Other species that have been recorded by the above authors are, however, open to doubt. In both these collections the mode of capture was the same: a fine muslin bag was attached to a bath-room tap and the water was allowed to strain through it. I have already pointed out that this water does not come directly from the sea, but is first pumped into tanks from which the baths are supplied. Several species were obtained while the vessel was passing through the Suez Canal from Port Said to Suez, and it thus seems clear that the water sampled during this passage was almost certainly obtained from the eastern part of the Mediterranean. It is not surprising therefore to find in their collections certain species that are known to be inhabitants of the Mediterranean Sea or the Atlantic Ocean, namely,

Pseudocalanus elongatus (Boeck) (= *minutus* Kröyer),
Temoropia mayumbæensis (T. Scott),
Acartia longiremis (Lillj.),
A. (*Paracartia*) *dubia* T. Scott (? = *latisetosa* (Kricz.),
Corycæus (*Onychocorycæus*) *ovalis* Claus,

but these cannot be regarded as part of the fauna of the Suez Canal and the Gulf of Suez.

Very few species appear to have had their origin in the Gulf of Suez and the Suez canal; the total number of these appears to be five, namely,

Pseudocyclops umbraticus Giesbr.,
P. reductus Nicholls,
Calanopia media Gurney,
Acartia (*Acanthacartia*) *fossæ* Gurney,
Corycæus (*Onychocorycæus*) *medius* Gurney,

while two others seem to have originated in the Red Sea, namely,

Labidocera orsinii Giesbr.
Tortanus (*Atortus*) *recticauda* A. Scott.

Regarding the possibility of species making their way through the Suez Canal into the Mediterranean Sea, it has been well established that several of the more powerful swimmers, such as fish, or the active bottom-dwelling crustacea have been able to survive the passage and have penetrated into the Mediterranean Sea; but with the planktonic Copepoda the picture is a different one. Munro Fox (1926, p. 24) remarks, " the all-important fact from the point of view of animal distribution . . . is that for 10 months of the year—from October to July—the high density of the Bitter Lake water extends along the Canal as far north as kilometre 10, near Port Said. In the remaining months of August and September, on the contrary, the low-density water of Port Said penetrates into the Canal beyond Lake Timsah. This can only mean that from October to July a current flows from the Great Bitter Lake to the North, while in August and September the direction of the current is reversed and it flows to the south." Munro Fox (*loc. cit.*, p. 26) also points out that " currents are normally absent in the Bitter Lakes, except within 5 kilometres of the southern end of the Little Bitter Lake, where the tidal stream from Suez may still be felt. . . . Although Red Sea animals and plants can be transported rapidly by the tidal currents as far as the Little Bitter Lake, their further advance to the northern end of the Great Lake must be slow." A further check to " migration " may be the high salinity that still prevails in the Great Bitter Lake, which ranges from 48·5 to 52·2°/$_{\circ\circ}$ at the present day and which, when the canal was first opened, was as high as 68·9°/$_{\circ\circ}$.

Munro Fox (in Gurney, 1927, p. 171) in his table of distribution of the planktonic Copepoda within the limits of the canal shows that there is a steady fall in the numbers present as we pass from Suez Bay and Port Taufiq, with 18 and 19 species respectively, to the Bitter Lakes with 15, Lake Timsah with 13 and Kantara at Km. 45 only 4; further north the number present rises again to 10 at Km. 35 and 11 at Port Said, but this rise is due to the entry of species from the Mediterranean Sea, such as—

Paracalanus parvus Claus, northern form, *borealis* Wolfend.
? *Temora stylifera* (Dana).
? *Acartia* (*Acartiura*) *clausi* Giesbr.
A. (*Paracartia*) *latisetosa* (Kriczagin).
Oithona nana Giesbr., typical form.
Corycæus (*Ditrichocorycæus*) *brehmi* Steuer.
Centropages ponticus Karawiew.
? *Euterpina acutifrons* (Dana).
? *Oncæa media* Giesbr.

Thanks to the work of the following authors, Brady (1878–81, 1883), Thompson (1887, 1888, 1893, 1895, 1896, 1897, 1900), Thompson and A. Scott (1897, 1903), T. Scott (1894, 1897–1905, 1912, 1914), Sars (1901–03, 1903–11, 1913–18, 1919–21, 1925), Cleve (1900, 1901, 1904), Farran (1903, 1905, 1908, 1911, 1926, 1929), Giesbrecht (1892), Pearson (1906), van Breemen (1908), Wolfenden (1904, 1911), Norman and T. Scott (1906), Esterly (1911), Sharpe (1911), Dahl (1912), Pesta (1916), Candeias (1929), Steuer (1923, 1926), Wheeler (1901), Willey (1919), Wilson (1932*a* and *b*, 1942) and others, our knowledge of the Copepod fauna of the Atlantic Ocean is more complete than that of the other two great oceans, Pacific and Indian, and I have been able to collate records of no less than 138 warm-water epi-planktonic species from the south temperate and tropical regions of the South Atlantic Ocean. In this area we have a great counter-clockwise movement of the surface water, and the whole region corresponds to a part of Steuer's zoo-geographical tropical Atlantic region and his southern sub-tropical Atlantic sub-region. The Indo-Pacific species present in this area are as follows :

**Nannocalanus minor* (Claus).
**Canthocalanus pauper* (Giesbr.)
**Undinula darwini* (Lubb.).
**U. vulgaris* (Dana).
**Eucalanus crassus* Giesbr.
**E. monachus* Giesbr.
**E. mucronatus* Giesbr.
**E. pileatus* Giesbr.
**E. subcrassus* Giesbr.
**E. subtenuis* Giesbr.
**Rhincalanus cornutus* Dana.
**Mecynocera clausi* Thompson.
**Paracalanus aculeatus* Giesbr.
**P. crassirostris* F. Dahl.
**P. parvus* (Claus).
Acrocalanus longicornis Giesbr.
Calocalanus contractus Farran.
**C. pavo* (Dana).
C. plumulosus (Claus).
**Clausocalanus arcuicornis* (Dana).
**C. furcatus* (Brady).
Pseudocalanus minutus Kröyer (= *elongatus* (Boeck)).
**Euchæta acuta* Giesbr.
**E. concinna* Dana.
**E. marina* (Prestand.).
E. philippi Brady.†
**Scolecithrix danæ* (Lubb.).
Scolecithricella bradyi (Giesbr.).
S. dentata (Giesbr.).
**S. minor* (Brady).
**Centropages brachiatus* (Dana).

† This species is of doubtful validity.

*C. *calaninus* Dana.
*C. *furcatus* (Dana).
C. *gracilis* (Dana).
C. *violaceus* Brady.
**Pseudodiaptomus serricaudatus* (T. Scott).
**Temora longicornis* (Mull.).
*T. *stylifera* (Dana).
T. *turbinata* (Dana).
**Lucicutia flavicornis* (Claus).
C. *æthiopica* Dana.
*C. *bipinnata* Giesbr.
Candacia bispinosa Claus.
*C. *curta* Dana.
C. *longimana* Claus.
*C. *pachydactyla* Dana.
C. *pectinata* Brady.
C. *inermis* Cleve (= *rotundata* Wolfend., *obtusa* Sars).
C. *simplex* Giesbr.
*C. *truncata* Dana.
*C. *varicans* Giesbr.
**Labidocera acuta* (Dana).
L. *acutifrons* (Dana).
L. *detruncata* (Dana).
L. *wollastoni* (Lubb.).
**Pontella fera* Dana.
*P. *securifer* Brady.
P. *spinipes* Giesbr.
Pontellopsis perspicax (Dana).
P. *regalis* (Dana).
P. *villosa* Brady.
**Pontellina plumata* Dana.
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*Acanthacartia*) *tonsa* Dana.
A. (A.) *plumosa* T. Scott.
A. (*Odontacartia*) *centrura* Giesbr.
*A. (*Planktacartia*) *danæ* Giesbr.
A. (P.) *negligens* Dana.
A. *laxa* Dana.†
A. *denticornis* Brady.†
Oithona atlantica Farran.
O. *attenuata* Farran.
O. *brevicornis* Giesbr.
*O. *fallax* Farran.
O. *hamata* Rosendorn.
*O. *nana* Giesbr.

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† This species is of doubtful validity.

**O. plumifera* Baird.
O. pseudofrigida Rosendorn.
O. robusta Giesbr.
O. setigera (Dana).
**O. similis* Claus.
O. simplex Farran.
O. tenuis Rosendorn.
O. vivida Farran.
Paroithona parvula Farran.
**Oncæa conifera* Giesbr.
**O. media* Giesbr.
**O. mediterranea* Claus.
**O. subtilis* Giesbr.
**O. venusta* Philippi.
**Lubbockia squillimana* Claus.
Corycæus (*Corycæus*) *clausi* F. Dahl.
*? *C.* (*C.*) *crassiusculus* Dana.
**C.* (*C.*) *speciosus* Dana.
**C.* (*Monocorycæus*) *robustus* Giesbr.
C. (*Agetes*) *flaccus* Giesbr.
**C.* (*A.*) *limbatus* Brady.
C. (*A.*) *typicus* Kröyer.
**C.* (*Urocorycæus*) *furcifer* Claus.
C. (*U.*) *lautus* Dana.
C. (*Ditrichocorycæus*) *minimus* F. Dahl.
C. (*Onychocorycæus*) *agilis* Dana.
C. (*O.*) *catus* F. Dahl.
C. (*O.*) *giesbrechti* F. Dahl.
C. (*O.*) *latus* Dana.
**C.* (*O.*) *obtusus* Dana.
C. (*Corycella*) *curtus* Farran.
**C.* (*C.*) *gracilis* Dana.
**C.* (*C.*) *rostratus* Claus.
**Sapphirina angusta* Dana.
**S. auronitens* Claus—*sinuicauda* Brady.
S. gastrica Giesbr.
S. intestinata Giesbr.
**S. iris* Dana.
S. lactens Giesbr.
S. maculosa Giesbr.
S. metallina Dana.
**S. nigromaculata* Claus.
**S. opalina* Dana—*darwini* Haeckel.
**S. ovatolanceolata* Dana—*gemma* Dana.
**S. scarlata* Giesbr.
S. stellata Giesbr.

Copilia lata Giesbr.
C. mediterranea (Claus).
C. mirabilis Dana.
C. quadrata Dana.
C. vitrea (Haeckel).
Ectinosoma melaniceps Boeck.
E. normani T. and A. Scott.
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
**Macrosetella gracilis* (Dana).
Miracia efferata Dana.
Clytemnestra rostrata (Brady).
C. scutellata Dana.
**Ægisthus aculeatus* Giesbr.
**Æ. mucronatus* Giesbr.

If, as seems probable, the majority of these species have been carried westward from the Indo-Pacific region to the Atlantic Ocean by the surface current round the Cape of Good Hope, one would expect to find that a large proportion of them might, at one time or another, have been taken in the Cape region.

Dahl (1894) put forward the view that at the southern point of Africa a cold Atlantic current meets a warm Indo-Pacific current, so that a mixture and an exchange of the respective tropical forms cannot take place, and that since the connection between the Atlantic and Pacific Oceans was interrupted in the Tertiary period by the upheaval of Central America, similar and yet somewhat divergent forms have developed in the two oceans. Meissenheimer (1905) and others have called attention to the manner in which the warm water of the Agulhas Current from the Indian Ocean meets the cool water of the West Wind Drift, and is bent first southwards and then eastwards to flow parallel with it, while a branch of the cool West Wind Drift turns northwards along the west coast of Africa and becomes mixed with cold upwelling water to form the Benguela Current, that in its turn swings towards the north-west and becomes the South Atlantic Equatorial Current. Steuer (1928) maintains that while the upwelling water renders the development of a rich plankton possible, the change from a warm to a luke-warm temperature brought about by the upwelling and the admixture of cool water causes many steno-thermic planktonic organisms to die out. This admixture of cool surface water and cold upwelling water undoubtedly forms a barrier to the westerly extension of some species, and doubtless is one factor in the preservation of the differences that exist between the plankton of the Indo-Pacific and Atlantic regions, but its effects should not be over-rated. Cleve (1904) studied the Copepoda of this region, and in the Introduction to his paper attempted to correlate the water movements with the distribution of the various species. He expressed the view that "it might be expected that the waters of the Agulhas Bank would possess a kind of plankton different from that of the waters east of South Africa," and he concluded from his researches that this had been proved to be the case. He drew attention to the manner in which the mixed waters of the Agulhas Current and the West Wind Drift flow eastward across the southern part of the Indian Ocean, sending a branch northwards along the west coast of Australia and then, after crossing the Pacific Ocean, " a very mighty one when it meets the south end of America or the north-going Humboldt Current " ; to this he attributed the presence off South Africa of numerous species that are common to that region and to the west coast of South America. Cleve also put forward the view that " the waters of the temperate Atlantic in the Northern Hemisphere originate, not in the Gulf Stream, but from the Benguela Current, which is supposed to pass as an under-current below the waters of the tropical Atlantic " ; and to this he attributed the fact that " of the Copepoda found south and west of the Cape Colony a considerable number also occur in the Northern Hemisphere, north of a line traced from the Newfoundland Banks to the Azores and the Cape Verde Islands, some so far to the north that they pass through the Faröe Channel and reach the coasts of Scandinavia." Unfortunately Cleve does not discriminate between those species that live in the upper levels and thus inhabit the water of the Agulhas and Benguela currents and those that occur at considerable depths, where they would be quite unaffected by movements of the surface water ; nor to-day will anyone agree that the water of the Benguela Current flows northwards beneath the warm water of the tropical region of the Atlantic.

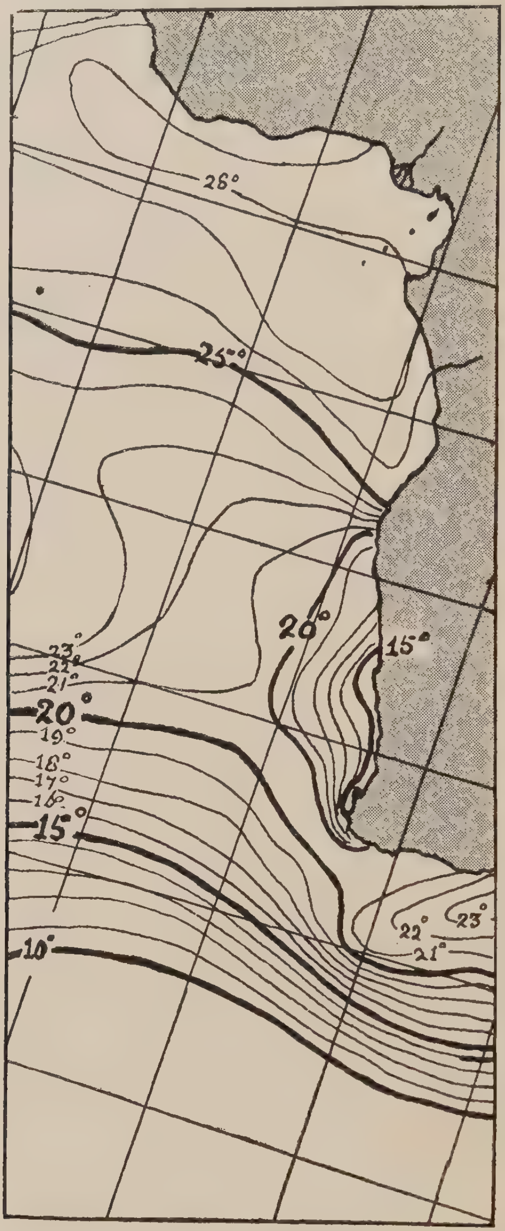
Michaelis (1923) has shown that a branch of the Agulhas Current flows westward from the Indian Ocean round the Cape of Good Hope into the Atlantic Ocean. Stephenson (1944), from his study of the intertidal fauna and flora of the region of the Cape of Good Hope, concludes that as one passes from east to west " the most rapid disappearance of species takes place as the mean annual temperature falls distinctly below 20° C." Steinitz (1929) has pointed out that in the summer month of February in the South Hemisphere the isotherm of 20° C. runs about 2 degrees of latitude to the south of the southernmost point of South Africa, and in consequence temperature offers no bar during this season to the free admixture of the warm-water plankton of the Indian and Atlantic Oceans. Schott (1935) confirms this, and points out that this westerly branch of the Agulhas Current flows against the prevailing wind, which, during the greater part of the year, blows from the west ; and still more recently Deacon (1937, p. 75) also agrees that " a small portion of the (Agulhas) current passes round and over the (Agulhas) Bank and turns towards the north round the Cape of Good Hope." The charts published by the Koninklijk Nederlandsch Meteorologische Instituut (1924–30) show that this westerly flow of water from the Agulhas Current to the Benguela Current is absent during the months June–August ; it commences to flow, though to a slight extent only, in September–November, and reaches its maximum in February–March, when it reaches a velocity of 5·0–9·9 miles per day, and then dies away again. The isotherms of the surface water show that as the water moves westward its temperature falls to some extent—

In December from 20·0° C. to 17·5° C.
,, February ,, 22·5° C. ,, 20·0° C.
,, April ,, 22·0° C. ,, 17·5° C.
,, June to November ,, 20·0° C. ,, 15·0° C.

Thus during the earlier part of the year, from December to April, epi-planktonic organisms that are swept westward from the Indian Ocean into the Atlantic will experience a fall of only 2·5° C., and it is during these months that the effect of the North-east Monsoon will be greatly to increase the strength of the Agulhas Current ; it seems probable that only those species that are least resistant and most susceptible to temperature changes will materially be affected. Much will, however, depend on the position in the temperature scale of the critical temperature below which individuals of the warm-water species are unable to breed ; if, as suggested by Stephenson, this lies at about 20° C., the ability to get from one ocean to the other will to some, and perhaps to a great extent, be dependent on the length of time that temperatures above this are to be found off the southern point of Africa ; the data given above suggest that such a condition only persists for a relatively short period, since in both December and April the water masses get cooled to about 17·5° C. Marchand (1932) has shown that in December, 1930, the temperature of the sea water at Cape Agulhas was 20·0° C., but that to the west of this and as far up the West African coast as Walvis Bay the surface temperature was considerably less, being as low as 11·6° C. at Port Nolluth. But this low temperature is a feature of the inshore water and is a result of the upwelling of cold water ; further seaward the water of the Atlantic Ocean has a temperature of over 15° C. and the isotherm of this temperature runs from east to west well to the south of the Cape region, though no water of 20° C. gets much further than the longitude of Port Elizabeth or 24° E. In the month of February, according to Schott (1902, pl. viii) the 20° isotherm runs well to the south of the Cape, and between the cool water of the West Wind Drift and the inshore cold area of upwelling water of the Benguela Current there is a wide warm-water corridor in which the temperature is at least 20° C. on the surface (*vide* Text-fig. 86). If, however, the critical temperature is, as I have suggested above (*vide supra*, p. 343), nearer to 15° C., there will be, so far as this factor is concerned, little or no obstruction to the passage westward of surface-living species, since the 15° C. isotherm runs at all seasons of the year well to the south of the Cape, and the extent to which the passage from the Indian Ocean to the Atlantic can be made will depend for the most part on the amount of water that is flowing in this direction and the degree of eddy movement and consequent mixing that takes place between the Agulhas and Benguela Currents. It is possible, however, that in times past the facilities for the transport of warm-water planktonic organisms from east to west were greater owing to the sea temperature being somewhat higher than it is to-day. Stanley Gardiner (1931, p. 159) has called attention to the fact that in latitudes to the south of about 17°–20° near the southern limit of coral-reef formation, the reefs at the present time appear to be undergoing a process of regression, leaving to seaward at a depth of about 30–40 fathoms a broad shelf, and he suggests that these reefs are being removed by erosion, and that " the only cause of such removal or regression of reefs is a lowering of the temperature of the sea such as would kill the growing organisms which cover them, and it is noticeable that all these reefs with shelves are situated near the line of ocean temperature critical to reef corals. If temperature is the cause of their regression, they are explicable on the supposition of a still actively progressing glacial period in the southern hemisphere."

Steuer (1933) thinks that it is possible that in certain years the barrier between the Indian and Atlantic faunas at the southern end of Africa is broken down, but he adds, " nevertheless it appears to come to this, that Indian forms in the long run do not survive in the Atlantic." In reaching this decision he appears to me to have been over-influenced by the presence in the two regions of distinct races of the species *Rhincalanus cornutus*, f. *typicus* in the Indo-Pacific region and f. *atlanticus* in the Atlantic Ocean.

At the commencement of the Tertiary Epoch there was a direct connection through the tropical region between the Indo-West Pacific area and the Atlantic Ocean by means of the Tethys Sea. In Miocene times this highway was finally closed by the elevation of the Alpine-Himalayan mountain range; but it may be argued that the presence of so many species in these two regions at the present time is attributable to this ancient connection. If, however, this were the true explanation I feel that the differences between the two faunas would be far greater than it is, and I believe that of the 138 species listed above, by far the greater number have been carried in more recent times by currents round the Cape of Good Hope from east to west. If this be the case one would expect to find that a large proportion of the species present on the two sides of South Africa have at one time or another been taken in the Cape region. Comparatively little work has been



Text-fig. 86.—The temperature of the surface water off the South-west coast of Africa in February. (After G. Schott, 1902.)

carried out in this area, but, even so, a number of these species have been taken, and I have indicated these in the above list by an asterisk. It is, I think, justifiable to conclude that in the past a number of the more hardy species have managed to survive the comparatively sudden transition from the warm water of the Agulhas Current to the cool water of the Benguela Current and thus have reached the Atlantic Ocean. It is not necessary, however, to assume that such a transference of species westwards is going on continually, and it is possible that only under exceptional meteorological conditions, such as an increase in the strength of the north-east monsoon wind, does sufficient warm water find its way westward to minimize the sudden fall of temperature in the surface water, and so enable plankton to be swept round the Cape of Good Hope into the Atlantic Ocean in a viable condition.

In a few instances this transfer from east to west appears to have been accompanied by slight structural changes that have given rise to separate Indo-Pacific and Atlantic forms of the same species ; such a change has been brought about in the following species :

Indo-Pacific form.	Atlantic form.
Rhincalanus cornutus f. *typicus* Dana	*Rhincalanus cornutus* f. *atlanticus* Schmaus.
Corycæus minimus indicus M. Dahl.	*Corycæus minimus minimus* F. Dahl.
Paracalanus parvus (Claus), f. *indicus* Wolf.	*Paracalanus parvus*, f. *borealis* Wolf.
? *Oithona nana* Giesbr., southern form	*Oithona nana*, northern form.
Corycæus (*Corycella*) *rostrata* Claus	*Corycæus* (*Corycella*) *rostrata* var. *longa* Klevenhusen.

Cleve (1901) attempted to define certain types of plankton that are to be found in different regions of the Atlantic Ocean, and to some extent he further attempted to correlate these types with the known movements of the surface water ; he recognized one such type, which he termed " Desmoplankton," as prevailing throughout the whole of the tropical and temperate region of the South Atlantic between Africa and South America and in the Equatorial Current. A second such type, which he termed " Styliplankton," constitutes the plankton of the Gulf Stream water and has a range of distribution from the west of South Africa, the Benguela Current and the Gulf of Guinea, and further to the north is found in the eastern part of the North Atlantic in the region of the Cape Verde, Canary and Azores Islands and at the mouth of the English Channel. Yet another type he termed " Trichoplankton," and this is characteristic of the region between Spitzbergen and Greenland, and is carried westward round Cape Farewell and up the west coast of Greenland, and so into the Labrador Current and down the east coast of North America as far as New York. Since that date a considerable amount of work has been carried out on the correlation of distribution of planktonic organisms and the surface currents.

Assuming that these 138 Indo-Pacific species have been swept westward from the Indian Ocean past the Cape of Good Hope into the Atlantic Ocean, their subsequent distribution will clearly depend on the surface circulation in this latter area. From the Benguela Current these organisms will be carried on into the South Equatorial Current, and so be transported across the Atlantic towards the north-east corner of South America, opposite which this current divides into two main streams. One of these branches turns in a southwesterly direction and runs parallel to the Brazilian coast, where it is known as the Brazil Current (*vide* Chart I). In about lat. 30° S. this current swings away from the coast and becomes separated from it by the cold northwardly-flowing Falkland Island Current. Still further south in about lat. 40° S. the Brazil Current is deflected sharply to the east and flows back again across the Atlantic basin parallel to the West Wind Drift, and between these two masses of water lies the South Atlantic sub-tropical convergence zone. Off the south-west corner of the Cape the current again swings to the north-east and joins the Benguela Current. This great counter-clockwise movement of the surface-water comprises the geographical area that Steuer (1933, p. 293) terms the Southern Sub-tropical Atlantic sub-region.

Our knowledge of the Copepod fauna of the western part of the South Atlantic is still very incomplete; but the investigations of Brady (1883), F. Dahl (1894*a*), T. Scott (1912), Farran (1929) and Klevenhusen (1933) have recorded the following species in this area:

Nannocalanus minor (Claus).
Undinula darwini (Lubb.).
U. vulgaris (Dana).
Eucalanus crassus Giesbr.
E. subcrassus Giesbr.
E. vadicola F. Dahl.
Rhincalanus cornutus (Dana), f. *atlantica* Schmaus.
Mecynocera clausi Thompson.
Paracalanus aculeatus Giesbr.
P. crassirostris F. Dahl.
P. parvus (Claus).
Acrocalanus longicornis Giesbr.
Calocalanus pavo (Dana).
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
Ctenocalanus vanus Giesbr.
Euchæta marina (Prestand.).
Scolecithrix danæ (Lubb.).
Drepanopus forcipatus Giesbrecht.
Centropages calaninus (Dana).
C. furcatus (Dana).
C. violaceus (Claus).
Pseudodiaptomus acutus (F. Dahl).
P. gracilis (F. Dahl).
P. marshi Wright.
P. richardi (F. Dahl).
Temora stylifera (Dana).
Lucicutia flavicornis (Claus).
Candacia bipinnata Giesbr.
C. bispinosa Claus.
C. curta Dana.
C. pachydactyla Brady.

C. simplex Giesbr.
Calanopia americana F. Dahl.
Labidocera acutifrons (Dana).
L. braziliense Farran.
L. detruncata (Dana).
L. fluviatilis F. Dahl.
L. nerii (Kröyer).
Pontella patagoniensis (Lubb.).
P. securifer Brady.
P. spinipes Giesbr.
Pontellopsis brevis (Giesbr.).
P. perspicax (Dana).
P. regalis (Dana).
P. villosa Brady.
Pontellina plumata Dana.
A. (*Acauthacartia*) *giesbrechti* F. Dahl.
Acartia (*Planktacartia*) *danæ* Giesbr.
A. (*P.*) *negligens* Dana.
A. (*Odontacartia*) *lilljeborgi* Giesbr.
A. denticornis Brady.
Oithona amazonica Burckhardt.
O. minuta T. Scott.
O. plumifera Baird.
O. setigera (Dana).
O. simplex Farran.
O. similis Claus.
Oncæa conifera Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. venusta Philippi.
O. venusta var. *vanella* Farran.
Corycæus (*Corycæus*) *clausi* F. Dahl.
C. (*C.*) *crassiusculus* Dana.*
C. (*C.*) *speciosus* Dana.
C. (*Agetes*) *flaccus* Giesbr.
C. (*A.*) *limbatus* Brady.
C. (*A.*) *typicus* Kröyer.
C. (*Urocorycæus*) *furcifer* Claus.
C. (*U.*) *lautus* Dana.
C. (*Ditrichocorycæus*) *amazonicus* F. Dahl.
C. (*D.*) *minimus* F. Dahl, f. *uncinatus* Klevenhusen.
C. (*Onychocorycæus*) *giesbrechti* F. Dahl.

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* M. Dahl (1912, p. 129) maintains that *Corycæus crassiusculus* is an Indo-Pacific species and does not occur in the Atlantic Ocean, where it is replaced by *Corycæus clausi*. Farran (1929, p. 292) notes that the specimens examined by him from New Zealand were intermediate between *crassiusculus* and *clausi*, and it seems doubtful if the distinction between these two species can be maintained.

C. (*O.*) *latus* Dana.
C. (*O.*) *obtusus* Dana.
C. (*O.*) *ovalis* Claus.
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *gracilis* Dana.
C. (*C.*) *rostratus* Claus.
Sapphirina angusta Dana.
S. auronitens Claus—*sinuicauda* Brady.
S. intestinata Giesbr.
S. iris Dana.
S. lactens Giesbr.
S. nigromaculata Claus.
S. opalina Dana—*darwini* Haeckel.
S. ovatolanceolata Dana—*gemma* Dana.
Copilia lata Giesbr.
C. mirabilis Dana.
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
Miracia efferata Dana.

Of these 93 species no less than 71 (or 72 if we include *Corycella gracilis*, the eastern records of which appear to be open to doubt) have been recorded from, and are widespread inhabitants of, the Indian Ocean, and 43 have been recorded from the region of the Cape of Good Hope and 36 in the Gulf of Guinea. Two species, namely, *Drepanopus forcipatus* and *Acartia lilljeborgi* have in all probability been carried eastward from the south Pacific area in the West Wind Drift past Cape Horn and then have been swept northwards up the American coast in the Falkland Islands Current (*vide supra*, p. 405).

A certain number of species that have been recorded from this region of the east coast of South America appear to be indigenous; some of these are marine in their habitat, namely:

Calanopia americana F. Dahl.
Labidocera braziliense Farran.
Pontella patagoniensis (Lubb.).
Pontellopsis brevis (Giesbr.).

Others appear to have evolved in the brackish water of the great river estuaries, namely:

Eucalanus vadicola F. Dahl.
Pseudodiaptomus acutus (Dahl).
P. gracilis (Dahl).
P. marshi Wright.
P. richardi (Dahl).
Labidocera fluviatilis Dahl.
Oithona amazonica Burckhardt.
Corycæus (*Ditrichocorycæus*) *amazonicus* F. Dahl.
Acartia (*Acanthacartia*) *giesbrechti* F. Dahl.

None of these has as yet been recorded outside the region of the east coast of South America, with the single exception of *Calanopia americana*; as Farran (1929, p. 211) has pointed out, this species is confined to the west side of the Atlantic, but its distribution is not so restricted as that of the others; it was originally taken in the estuary of the Amazon River, but it has since been recorded by A. Scott (1909, p. 181) from Bermuda in the North Atlantic, and by Jespersen (1940, p. 67) from Iceland in lat. 62° 40′ N., long. 19° 05′ W. For the rest it seems probable that they are endemic on the east coast of South America.

We have already seen that in about lat. 35°–40° S. the water mass of the Brazil Current swings eastward and runs across the South Atlantic Ocean parallel to and on the north side of the West Wind Drift; a similar arrangement of the current systems is found in the Indian Ocean, where the Agulhas and Madagascar Currents bend eastward, and again in the south-west area of the Pacific Ocean, where the East Australian Current swings eastward past New Zealand. In all three oceans between these various current systems and the West Wind Drift lies the Sub-tropical Convergence Zone, and though there is, of necessity, a certain amount of mixing of the two water masses along the line, the transition from warm to cool conditions appears to form a barrier to the southward extension of a number of species. In all three oceans it is, however, possible for the more hardy species to survive transference across the Convergence Zone and so to become inhabitants of the West Wind Drift. As this great current system is circum-terrestrial, it seems probable that all species found in it will equally possess a circum-terrestrial distribution, and I have assumed that this is so. The species that have so far been recorded from the region of the West Wind Drift are the following:

Nannocalanus minor (Claus).
Undinula darwini (Lubb.).
Eucalanus longiceps Matthews (= *acus* Farran).
E. subtenuis Giesbr.
Mecynocera clausi Thompson.
Paracalanus parvus (Claus).
Calocalanus pavo (Dana).
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
C. pergens Farran.
Ctenocalanus vanus Giesbr.
Microcalanus pygmæus Sars.
Euchæta marina (Prestand.).
Scolecithricella minor (Brady).
Centropages brachiatus (Dana).
C. violaceus (Claus).
Temora turbinata (Dana).
Candacia cheirura Cleve.
C. truncata Dana.
Labidocera acutifrons (Dana).
Acartia (Acartiura) clausi Giesbr.

A. (*Planktacartia*) *danæ* Giesbr.
Oithona plumifera Baird.
O. similis Claus.
Oncœa conifera Giesbr.
O. curvata Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. notopus Giesbr.
Conea rapax Giesbr.
Corycæus (*Corycæus*) *speciosus* Dana.
C. (*Agetes*) *flaccus* Giesbr.
C. (*Uricorycæus*) *furcifer* Claus.
C. (*Corycella*) *gracilis* Dana.
C. (*C.*) *rostratus* Claus.
Sapphirina metallina Dana.
S. scarlata Giesbr.
S. nigromaculata Claus.
S. ovatolanceolata Dana—*gemma* Dana.
Ectinosoma melaniceps Boeck (= *australe* Sars, *antarcticum* Giesbr.).
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
Macrosetella gracilis (Dana).
Clytemnestra rostrata (Brady).

In addition to the above species, that appear to have been swept by admixture of the water masses from the sub-tropical zone of one or all of the three great oceans into the West Wind Drift, certain other species appear to have been evolved in this current system; such species are—

Clausocalanus laticeps Farran,
C. paululus Farran,
Drepanopus forcipatus Giesbr.,
D. pectinatus Brady,
Centropages auklandicus Krämer (= *discaudatus* Brady),
Acartia (*Odontacartia*) *lilljeborgi* Giesbr.,
Temora kerguelensis Brady,
Copilia hendorffi Dahl,

and perhaps to these should be added *Candacia cheirura* Cleve,* which was first recorded by Cleve (1905, p. 186) from the west of South Africa in 250–450 m., and has since been taken by the "Terra Nova" to the south of New Zealand between the Auckland and Campbell Islands (*vide* Farran, 1929, p. 273), and *Scolecithricella neptuni* Cleve, which was taken with the former species off South Africa in 250–350 m.

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* Cleve, 1905, has given two different spellings for the specific name of this species; in his Table III on p. 182 and in the alphabetical list of species on p. 186 he spells it "*chirura*," but in his account of the species on p. 198 he gives the name as "*cheirura*," and this latter spelling is followed in the alphabetical index on p. 262.

It must not be overlooked that the West Wind Drift may have contributed certain species to the fauna of the South Atlantic, and especially to the south-east area. I have already (*vide supra*, p. 403) called attention to the fact that some 23 species that are known to be present in both the south-west and south-east regions of the Pacific Ocean, but are not known from the north-east area, may have been carried eastward across the South Pacific Ocean, and it is possible that they may have been swept in the West Wind Drift still further eastward, and have reached the region to the south-west of the Cape of Good Hope and have been caught up in the Benguela Current and so carried up the west coast of Africa. Such species are—

Drepanopus forcipatus Giesbr.
Centropages brachiatus (Dana).
Acartia denticornis Brady.

Drepanopus forcipatus Giesbr. has been taken off the west coast of South America, and Brady has also recorded it from off Cape Howe, Australia, and from the tropical region of West Africa in lat. 5° 28′ N., long. 14° 38′ W., off Sierra Leone, to which position it may have been carried by the Benguela Current. *Centropages brachiatus* (Dana), also known from the west coast of South America, has been recorded from off the Cape of Good Hope (Cleve, 1905) and in the Gulf of Guinea (T. Scott, 1894).

From the West Wind Drift a few of the most resistant species appear to have been able to survive transference across the Antarctic Convergence Zone into the South Polar region. The work of Giesbrecht (1902), Brady (1910), Wolfenden (1911), T. Scott (1912), Farran (1929), Mackintosh (1934), Hardy and Gunther (1935) and Wilson (1938) has demonstrated the presence of the following species in this southern area :

Nannocalanus minor (Claus).
Paracalanus parvus (Claus).
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
C. laticeps Farran.
Ctenocalanus vanus Giesbr.
Microcalanus pygmæus Sars.
Scolecithricella minor (Brady).
Drepanopus pectinatus Brady.
Labidocera acutifrons (Dana).
Oithona similis Claus.
Oncæa conifera Giesbr.
O. curvata Giesbr.
O. media Giesbr.
O. notopus Giesbr.
Conea rapax Giesbr.
Corycæus (*Corycæus*) *speciosus* Dana.
C. (*Agetes*) *flaccus* Giesbr.
C. (*Urocorycæus*) *furcifer* Claus.
Sapphirina metallina Dana.
Ectinosoma melaniceps Boeck (= *antarcticum* Giesbr.).
Microsetella norvegica (Boeck).
Macrosetella gracilis (Dana).

Some, and probably the majority, of these species may have been carried directly from the West Wind Drift into the Polar region by surface eddies, and this would seem to be most probable for such forms as *Clausocalanus laticeps* Farran and *Drepanopus pectinatus* Brady, which appear to have had their origin in the West Wind Drift. It is, however, possible that certain other species may have been swept southward in the deep Intermediate Currents, either in the Atlantic or the Indian Oceans, and so have reached the Sub-Antarctic region, where they have again been carried upwards to the surface. Hardy and Gunther (1935, p. 356) have suggested that such species as *Ctenocalanus vanus* Giesbr. and *Scolecithricella minor* (Brady) may by vertical migration pass from one current system to another, so that they, after being swept northwards by the Polar Current " to the limit of the Antarctic Zone, may descend . . . and make use of the great oceanic current system to return into the Antarctic Zone again in the intermediate layer flowing back towards the Pole." *Ctenocalanus vanus* Giesbr. and *Microcalanus pygmæus* Sars have almost certainly been swept by the North Atlantic intermediate current from the Atlantic Ocean to the Antarctic region; and it seems possible that several other species have traversed this route; *Nannocalanus minor* (Claus) was taken only once in the Antarctic region (*vide* Hardy and Gunther, 1935, p. 123) at a depth of 750–500 m., *Clausocalanus furcatus* (Brady) occurred in the Sub-Antarctic Zone between 1000 and 50 m., and Wolfenden (1911, pp. 366–369) has stated that *Oncæa conifera* Giesbr., *Sapphirina metallina* Dana, *Corycæus speciosus* Dana, *Oithona similis* Claus and *Labidocera acutifrons* (Dana) were captured in the South Polar region by the " Gauss " in depths of 1200–3000 m. along with numerous inhabitants of the North Atlantic Intermediate Current. Possibly *Candacia cheirura* Cleve has followed the same course; one of the two species of *Candacia* taken by the " Discovery " in the South Atlantic and recorded, but not identified, by A. Scott, in depths ranging from 100–0 m. (*vide* Hardy and Gunther, 1935) may be this species; the other species belonging to this genus is stated to be a new and unknown one.

On the north side of the Atlantic South Equatorial Current runs the Contra-equatorial Current, which passes from west to east into the Gulf of Guinea. Here also the bulk of the species of planktonic Copepoda that have been recorded appear to have been derived from the Indo-Pacific region. Thanks to the work of Brady (1883), T. Scott (1894), Cleve (1900), Wolfenden (1911), Pesta (1916), Steuer (1923) and Klevenhusen (1933) I have been able to compile the following list of species from this region:

Nannocalanus minor (Claus).
Undinula vulgaris (Dana).
Eucalanus mucronatus Giesbr.
E. setiger Brady,
Rhincalanus cornutus Dana, f. *atlantica* Schmaus.
Mecynocera clausi Thompson.
Paracalanus crassirostris F. Dahl, f. *scotti* Früchi.
P. parvus (Claus).
Calocalanus pavo (Dana).
C. plumulosus (Claus).
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
Drepanopus forcipatus Giesbr.

Euchæta acuta Giesbr.
E. hebes Giesbr.
E. marina (Prestand.).
Scolecithrix danæ (Lubb.).
S. scotti Giesbr.
Scolecithricella bradyi (Giesbr.).
S. minor (Brady).
Lophothrix latipes (T. Scott).
Centropages brachiatus (Dana).
C. furcatus (Dana).
C. violaceus (Claus).
Temora longicornis (O. F. Müller).
T. stylifera (Dana).
Temoropia mayumbæensis (T. Scott).
Pseudodiaptomus serricaudatus (T. Scott).
P. hessei (Mrazek).
Lucicutia flavicornis (Claus).
Candacia æthiopica Dana.
C. bispinosa Claus.
C. curta Dana.
C. longimana Claus.
C. pachydactyla Dana.
C. pectinata Brady.
C. truncata Dana.
C. varicans Giesbr.
Labidocera acuta (Dana).
L. acutifrons (Dana).
L. detruncata (Dana).
L. nerii (Kröyer).
L. scotti Giesbr. (= *darwini* T. Scott, *non* Lubb.).
Pontella gaboonensis T. Scott.
P. inermis Brady.
P. securifer Brady.
Pontellopsis villosa Brady.
Pontellina plumata Dana.
Acartia (*Acartiura*) *clausi* Giesbr. var. *gaboonensis* T. Scott.
A. (*Acanthacartia*) *bifilosa* (Giesbr.).
A. (*A.*) *plumosa* T. Scott.
A. (*Planktacartia*) *danæ* Giesbr.
A. (*P.*) *negligens* Dana.
A. laxa Brady.
A. denticornis Brady.
Paracartia africana Steuer.
P. dubia T. Scott (= *spinicaudata* T. Scott).
Oithona atlantica Farran.
O. fallax Farran.

O. hamata Rosendorn.
O. mediterranea (Claus.)
O. minuta T. Scott.
O. notopus Giesbr.
O. plumifera Baird.
O. pseudofrigida Rosendorn.
O. robusta Giesbr.
O. setigera (Dana).
O. tenuis Rosendorn.
O. venusta Philippi.
Conæa rapax Giesbr. (= *Oncæa gracilis* Dana).
Lubbockia squillimana Claus.
Corycæus (*Corycæus*) *speciosus* Dana.
C. (*Agetes*) *flaccus* Giesbr.
C. (*A.*) *limbatus* Brady.
C. (*Urocorycæus*) *furcifer* Claus.
C. (*Ditrichocorycæus*) *amazonicus* F. Dahl.
C. (*D.*) *africanus* F. Dahl.
C. (*D.*) *minimus* F. Dahl, f. *minimus*.
C. (*D.*) *minimus* var. *uncinatus* Klevenhusen.
C. (*Onychocorycæus*) *giesbrechti* F. Dahl.
C. (*O.*) *latus* Dana.
C. (*O.*) *obtusus* Dana.
C. (*O.*) *ovalis* Claus.
C. (*Corycella*) *gibbulus* Giesbr.
C. (*C.*) *gracilis* Dana.
Sapphirina auronitens Claus—*sinuicauda* Brady.
S. inæqualis Brady.
S. metallina Dana.
S. opalina Dana—*darwini* Haeckel.
S. serrata Brady.
Copilia lata Giesbr.
C. mediterranea (Claus).
C. mirabilis Dana.
C. quadrata Dana.
C. vitrea (Haeckel) (as *fultoni* T. Scott).
Pontœciella abyssicola (T. Scott).
Microsetella norvegica (Boeck).
Euterpina acutifrons (Dana).
Macrosetella gracilis (Dana).
M. oculata Sars.
Clytemnestra scutellata Dana.
Ægisthus mucronatus Giesbr. (as *longirostris* T. Scott).

Of these 101 species, 86, or 85 per cent., have been recorded from the Indo-Pacific region. A few "species" are of doubtful authenticity, such as *Pontella inermis* Brady, *Acartia laxa* Brady, and *A. denticornis* Brady. Several species appear to have made their appearance in this region, either in the Gulf of Guinea or on the West African Coast, such as:

Scolecithrix scotti Giesbr.
Pseudodiaptomus hessei (Mrazek).
Labidocera scotti Giesbr.
Pontella gaboonensis T. Scott.
Paracartia africana Steuer.
P. dubia T. Scott.

A few other species are Atlantic in their origin and appear to have been swept eastwards into the Gulf of Guinea by the Contra-equatorial Current; this would account for the presence of *Acartia bifilosa* (Giesbr.) and *Labidocera nerii* (Kröyer), while *Corycæus amazonicus* F. Dahl has almost certainly been carried eastward in a similar way.

Turning now to the tropical and temperate regions that lie to the north of the Equator and the Guinea Current, we have in this area another great circular turning movement of the surface water; commencing with the North Equatorial Current the water masses pass westward across the Atlantic, part is carried into the Caribbean Sea and the Gulf of Mexico and part sweeps towards the north-west outside the Antillean arc; the former leaves the Gulf of Mexico through the Florida Strait, and beyond this is again joined by the latter to form the Gulf Stream. This is continued as the North Atlantic Drift across the ocean towards the European coast and on the east side of the Atlantic divides into two streams, part going to the north of Scotland and on to Norway or, turning left-handed towards Iceland, forms the Irminger Current, and part turning southward off the coast of Portugal and then south-west, parallel to the coast of Morocco and French West Africa, to form the Canary Current (*vide* Chart I). This great clockwise movement encloses the Sargasso Sea, and the whole system corresponds to several of Steuer's zoo-geographical regions (*vide* Steuer, 1933, p. 293); thus the Gulf Stream and the North Atlantic Drift correspond to his Sub-Arctic Atlantic sub-region, while the Canary Current and the Sargasso Sea correspond to his Northern sub-tropical Atlantic sub-region. From this current system I have been able to compile records of the following 134 species, all of which are known from the Indo-Pacific region:

Nannocalanus minor (Claus).
Undinula darwini Lubb.
U. vulgaris (Lubb.).
Eucalanus crassus Giesbr.
E. monachus Giesbr.
E. mucronatus Giesbr.
E. subtenuis Giesbr.
Rhincalanus cornutus Dana.
Mecynocera clausi Thompson.
Paracalanus aculeatus Giesbr.
P. parvus (Claus).
Acrocalanus longicornis Giesbr.
Calocalanus contractus Farran.

C. pavo (Dana).
C. plumulosus (Claus).
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
C. pergens Farran.
Pseudocalanus minutus Kröyer.
Euchæta acuta Giesbr.
E. hebes Giesbr.
E. marina (Prestand.).
E. media Giesbr.
E. philippi Brady.
E. pubera Sars.
Scolecithrix danæ (Lubb.).
Scolecithricella bradyi (Giesbr.).
S. dentata Giesbr.
S. minor (Brady).
Centropages brachiatus (Dana).
C. bradyi Wheeler.
C. furcatus (Dana).
C. gracilis (Dana).
C. kröyeri Giesbr.
C. violaceus Brady.
Temora longicornis Baird.
T. stylifera (Dana).
T. turbinata (Dana).
Lucicutia flavicornis (Claus).
Candacia æthiopica Dana.
C. bipinnata Giesbr.
C. bispinosa Claus.
C. curta Dana.
C. inermis Cleve (= *obtusa* Sars).
C. longimana Claus.
C. pachydactyla Dana.
C. pectinata Brady.
C. simplex Giesbr.
C. tenuimana Giesbr.
C. truncata Dana.
C. varicans Giesbr.
Labidocera acuta (Dana).
L. acutifrons (Dana).
L. kröyeri (Brady).
L. wollastoni (Lubb.).
Pontella securifer Brady.
P. spinipes Giesbr.
Pontellopsis perspicax (Dana).

P. regalis (Dana).
P. villosa Brady.
Pontellina plumata Dana.
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*Acanthacartia*) *tonsa* Dana.
A. (*Odontacartia*) *centrura* Giesbr.
A. (*Planktacartia*) *danæ* Giesbr.
A. (*P.*) *negligens* Dana.
Oithona atlantica Farran.
O. brevicornis Giesbr.
O. nana Giesbr.
O. plumifera Baird.
O. pseudofrigida Rosendorn.
O. robusta Giesbr.
O. setigera Dana.
O. similis Claus.
O. simplex Farran.
O. tenuis Rosendorn.
O. vivida Farran.
Paroithona parvula Farran.
Oncæa conifera Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. minuta Giesbr.
O. subtilis Giesbr.
O. notopus Giesbr.
O. venusta Philippi.
Lubbockia aculeata Giesbr.
L. squillimana Claus.
? *Corycæus* (*Corycæus*) *crassiusculus* (? = *clausi* F. Dahl).
C. (*C.*) *speciosus* Dana.
C. (*Monocorycæus*) *robustus* Giesbr.
C. (*Agetes*) *flaccus* Giesbr.
C. (*A.*) *limbatus* Brady.
C. (*A.*) *typicus* Kröyer.
C. (*Urocorycæus*) *lautus* Dana.
C. (*U.*) *furcifer* Claus.
C. (*Ditrichocorycæus*) *minimus* F. Dahl.
C. (*Onychocorycæus*) *catus* F. Dahl.
C. (*O.*) *giesbrechti* F. Dahl.
C. (*O.*) *latus* Dana.
C. (*O.*) *obtusus* (? = *ovalis* Claus).
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *gracilis* Dana.
C. (*C.*) *rostratus* Claus.
Sapphirina angusta Dana.

S. auronitens Claus—*sinuicauda* Brady.
S. bicuspidata Giesbr.
S. gastrica Giesbr.
S. intestinata Giesbr.
S. iris Dana.
S. lactens Giesbr.
S. metallina Dana.
S. nigromaculata Claus.
S. opalina Dana—*darwini* Haeckel.
S. ovatolanceolata Dana—*gemma* Dana.
S. scarlata Giesbr.
S. stellata Giesbr.
Copilia lata Giesbr.
C. mediterranea (Claus).
C. mirabilis Dana.
C. quadrata Dana.
C. vitrea (Haeckel).
Ectinosoma melaniceps Boeck.
E. normani T. and A. Scott.
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
Macrosetella gracilis (Dana).
M. oculata Sars.
Miracia efferata Dana.
Clytemnestra rostrata (Brady).
C. scutellata Dana.
Ægisthus aculeatus Giesbr.
Æ. mucronatus Giesbr.

A comparison of the species in the above list with those that have been taken in the Southern Hemisphere in the counter-clockwise system of the South Atlantic reveals that a relatively few Indo-Pacific species have been reported from the North Atlantic, but have not as yet been taken in the south; these species are as follows:

Calocalanus styliremis Giesbr.
Euchæta media Giesbr.
Centropages bradyi Wheeler.
C. kröyeri Giesbr.
Candacia tenuimana Giesbr.
Oncæa minuta Giesbr.
Lubbockia aculeata Giesbr.
Sapphirina bicuspidata Giesbr.
Macrosetella oculata Sars.

It seems probable that further research will reveal their presence in the more southerly area. On the other hand, there are a number of Indo-Pacific species that have been taken in the South Atlantic, but have not, so far, been recorded from the North Atlantic ; these species are as follows :

Canthocalanus pauper (Giesbr.).
Eucalanus pileatus Giesbr.
Paracalanus crassirostris F. Dahl.
Euchæta concinna Dana.
Centropages calaninus Dana.
Pseudodiaptomus serricaudatus (T. Scott).
Labidocera detruncata (Dana).
Pontella fera Dana.
Acartia (*Acanthacartia*) *plumosa* T. Scott.
Oithona attenuata Farran.
O. fallax Farran.
O. hamata Rosendorn.
Corycæus (*Onychocorycæus*) *agilis* Dana.
Sapphirina maculosa Giesbr.

While some of these may be found by further research in the North Atlantic, it seems more probable, in view of the great amount of work that has already been carried out in this region, that these species have been able to get round the Cape of Good Hope into the southern area, but have not as yet been able to extend their habitat into the northern region.

In the water of the Gulf Stream the following Indo-Pacific species have been recorded (*vide* Wheeler, 1901, and Wilson, 1932 and 1942).

Nannocalanus minor (Claus).
Undinula vulgaris (Lubb.).
Eucalanus monachus Giesbr.
Rhincalanus cornutus Dana.
Mecynocera clausi Thompson.
Paracalanus parvus (Claus).
Calocalanus pavo (Dana).
C. plumulosus (Claus).
Clausocalanus arcuicornis (Dana).
Euchæta marina (Prestand.).
Scolecithrix danæ (Lubb.).
Centropages bradyi Wheeler.
C. furcatus (Dana).
Temora longicornis Baird.
T. stylifera (Dana).
Candacia armata Boeck (= *pectinata* Brady).
C. pachydactyla Dana.
Labidocera acutifrons (Dana).
Pontella securifer Brady.
Pontellopsis regalis (Dana).
Pontellina plumata Dana.

Acartia (*Acartiura*) *clausi* Giesbr.
A. (*Acanthacartia*) *tonsa* Dana.
A. (*Planktacartia*) *danæ* Giesbr.
Oithona atlantica Farran (as *spinirostris* Claus).
O. brevicornis Giesbr.
O. plumifera Baird.
O. similis Claus.
Oncœa minuta Giesbr.
O. venusta Philippi.
? *Corycæus* (*Corycæus*) *crassiusculus* Dana (? = *clausi* F. Dahl).
C. (*C.*) *speciosus* Dana.
C. (*Agetes*) *flaccus* Giesbr.
C. (*A.*) *typicus* Kröyer.
C. (*Urocorycæus*) *latus* Dana.
C. (*Ditrichocorycæus*) *minimus* F. Dahl.
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *gibbulus* Giesbr.
C. (*C.*) *gracilis* Dana.
C. (*C.*) *rostratus* Claus.
Sapphirina angusta Dana.
S. auronitens Claus—*sinuicauda* Brady.
S. nigromaculata Claus.
S. ovatolanceolata Dana—*gemma* Dana.
S. scarlata Giesbr.
Copilia denticulata Claus (= *mediterranea* Claus).
Ectinosoma normani T. and A. Scott.
Microsetella norvegica (Boeck).
M. rosea Dana.
Macrosetella gracilis (Dana).
M. oculata Sars.
Miracia efferata Dana.
Clytemnestra rostrata (Brady).
C. scutellata Dana.

And to these should be added the following species that, although not actually recorded from the Gulf Stream itself, have been taken in the near neighbourhood :

Eucalanus crassus Giesbr.
Scolecithricella minor (Brady).
Temora turbinata (Dana).
Lucicutia flavicornis (Claus).
Oithona nana Giesbr.
Oncœa conifera Giesbr.

We thus have as many as 59 Indo-Pacific species in the Gulf Stream off the coast of North America.

Species that inhabit the warm water of the Gulf Stream will be swept northwards and eastwards into the North Atlantic Drift and on towards the coasts of Europe, and will become part of the fauna of Steuer's Sub-Arctic Atlantic Sub-region. The actual distance to which such species may be carried and still survive will depend on their degree of resistance to cooling, and Rose (1920) has, under the heading "Distribution," noted that several of the above species appear to be present only in the western part of the North Atlantic, namely, to the west and south of the Azores and near the American coast; these species are—

Undinula vulgaris (Lubb.).
Centropages gracilis (Dana).
Candacia pachydactyla Dana.
Pontella securifer Brady.
Miracia efferata Dana.

Sapphirina auronitens-sinuicauda, *Corycæus lautus* and *Corycella gracilis* reach the Canary Islands and the coast of French West Africa, and *Candacia longimana* appears to have reached the Gulf of Gascony, but is not found further to the north. Other species of the genus *Sapphirina* also appear to die out in the North Atlantic; *Sapphirina gastrica* Giesbr. has been recorded from the coast of Mauretania in West Africa, and *S. bicuspidata* Giesbr., *S. intestinata* Giesbr., *S. maculosa* Giesbr., *S. lactens* Giesbr., *S. metallina* Dana and *S. scarlata* Giesbr. have all got into the Mediterranean Sea, though they have never been recorded to the north of lat. 40° N.

Within the tropical and temperate regions of the North Atlantic Ocean a number of species appear to have had their origin, namely:

Calocalanus tenuis Farran.
Scolecithricella ovata Farran.
Diaixis pygmæa T. Scott.
Pseudodiaptomus americanus Wright.
P. coronatus Wilson.
P. cristobalensis Marsh.
P. pelagicus Herrick.
Lucicutia gemina Farran.
Pseudocyclops magnus Esterly.
Lampoidopus marki Esterly.
Anomalocera patersoni Templ.
Pontella atlantica (M. E.).
P. lobiancoi Canu.
P. mediterranea Claus.
Parapontella brevicornis Lubb.
Acartia (Acartiura) bermudensis Esterly.
A. (Euacartia) macropus Cleve.
A. (Acanthacartia) spinata Esterly.
Corycæus (Ditrichocorycæus) anglicus Lubb.
C. (Onychocorycæus) latus Dana.
Halithalestris croni Kröyer.
Ægisthus atlanticus Wolfenden.

Æ. dubius Sars.*
Oncæa anglica Brady.
O. similis Sars.
O. tenella Sars.

And to these we should perhaps add—

Centropages chierchiæ Giesbr.
C. hamatus (Lillj.).
C. typicus Kröyer.

I have already called attention (*vide supra*, pp. 400, 410) to the fact that several species of Copepods that are known to inhabit the North Atlantic, and especially the Sub-Arctic region, have been recorded from the North Pacific Ocean, namely :

Centropages hamatus (Lillj.).
Temora longicornis (Müll.).
Anomalocera patersoni Templ.
Pontella atlantica (M. E.).
Acartia longiremis (Lillj.).
? *A. bifilosa* Giesbr. (as *A. clausi* Giesbr.).
Oncæa anglica Brady.
O. similis Sars.
O. tenella Sars.

None of these species is truly Arctic in its habitat, and it is possible that further researches may reveal that they are widely distributed, though of rare occurrence, in warmer waters ; but, if their distribution is so restricted and so discontinuous as appears to be the case at present, there must have been a connecting channel, in which conditions of temperature were suitable for their survival and reproduction, and by which they could be carried from one region to the other, but which has since, either by orographical or meteorological changes, been rendered impassable. One such channel in the tropical region was in existence in early Tertiary times between the Atlantic and Pacific Oceans across Central America, but since these species to-day are not tropical species, but rather temperate and cool water forms, it seems more probable that the connecting channel must be sought in the Arctic region. Berg (1934) has put forward the view that such a discontinuity can be accounted for by the climatic changes that were brought about at the close of the last glacial period ; at that time the northern climate became warmer, and during this warm post-glacial period species may have been able to extend their distribution along the north Asiatic coast and so pass through the Bering Strait, which was then open, into the North Pacific area. Berg quotes as examples of such distribution a number of Molluscs, among which are several Lamellibranchs, such as *Mytilus edulis* and *Modiola modiolus*, which must have carried out any extension of their habitat during their planktonic larval stage, and it seems probable that other planktonic organisms, such as the Copepoda, may have been carried from one ocean to the other during this warm period.

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* There is a possibility that this species, which is at present only known from the male, may be a synonym of *Ægisthus mucronatus* Giesbr. Sars has rejected this view, but Farran considers that the question is still open.

Ekman (1935, p. 239) agrees with Berg's view, though he points out that in those cases in which the actual species in the two oceans are not identical, though very closely related, the migration from one region to the other must have taken place at a more remote period, probably during the Tertiary epoch.

As the Gulf Stream and its continuation, the North Atlantic Drift, sweeps eastward across the North Atlantic Ocean the current divides into two main streams, one of which passes eastward towards the Bay of Biscay and the coast of Portugal, while the other passes towards the north-east to reach the channel between Iceland and Scotland (*vide* Chart I). Planktonic species that are carried eastward in the former branch may either reach the coast of Portugal, whence they will be swept southwards in the Canary Current past the entrance to the Mediterranean Sea, and by the inflowing surface current may be carried into that region, or else they may be swept into the Bay of Biscay or more to the north and so reach the coasts of the British Isles. Candeias (1929) has recorded the following species from the coast of Portugal :

**Nannocalanus minor* (Claus).
**Calanoides brevicornis* (Lubb.).
Eucalanus atlanticus Candeias.
**E. crassus* Giesbr.
**Paracalanus parvus* (Claus).
Pseudocalanus elongatus (Boeck).
**Clausocalanus arcuicornis* (Dana).
**Euchæta hebes* Giesbr.
**E. media* Giesbr.
**E. pubera* Sars.
**Scolecithrix danæ* (Lubb.).
**Scolecithricella bradyi* (Giesbr.).
**S. dentata* Giesbr.
**Temora longicornis* Baird.
**T. stylifera* (Dana).
**Centropages bradyi* Wheeler.
C. chierchiæ Giesbr.
**C. kröyeri* Giesbr.
**C. violaceus* Brady.
**Lucicutia flavicornis* (Claus.)
**Candacia armata* Boeck (= *pectinata* Brady).
**C. bipinnata* Giesbr.
Anomalocera patersoni Templ.
Labidocera wollastoni (Lubb.).
**Pontellopsis villosa* Brady.
**Acartia* (*Acartiura*) *clausi* Giesbr.
**A.* (*Planktacartia*) *danæ* Giesbr.
**Oithona similis* Claus.
**O. plumifera* Baird.
**Oncæa conifera* Giesbr.
**O. media* Giesbr.

**O. mediterranea* Claus.
**O. venusta* Philippi.
**Lubbockia aculeata* Giesbr.
**Corycæus (Agetes) flaccus* Giesbr.
**C. (Urocorycæus) lautus* Dana.
C. (Onychocorycæus) ovalis Claus.
**Sapphirina angusta* Dana.
S. escartiata Candeias.
**S. ovatolanceolata* Dana—*gemma* Dana.
**S. scarlata* Giesbr.
**Microsetalla rosea* Dana.

Of these 42 species as many as 35, marked with an asterisk, or 83 per cent., are Indo-Pacific forms.

A more northerly branch of the North Atlantic Drift sweeps eastward into the Bay of Biscay, and, thanks to Farran (1926), we have records of the following 33 Indo-Pacific epiplanktonic species from that area :

Nannocalanus minor (Claus).
Eucalanus crassus Giesbr.
Mecynocera clausi Thompson.
Paracalanus parvus (Claus).
Calocalanus contractus Farran.
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
C. paululus Farran.
C. pergens Farran.
Euchæta acuta Giesbr.
Scolecithricella dentata Giesbr.
Lucicutia flavicornis (Claus).
Candacia armata Boeck.
C. obtusa Sara (= *inermis* Cleve, *rotundata* Wolf.).
C. tenuimana Giesbr.
Acartia (Acartiura) clausi Giesbr.
Oithona atalantica Farran.
O. setigera Dana.
O. similis Claus.
Oncæa conifera Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. subtilis Giesbr.
Conœa rapax Giesbr.
Lubbockia aculeata Giesbr.
Corycæus (Urocorycæus) furcifer Claus.
Sapphirina nigromaculata Claus.
Vettoria granulosa (Giesbr.).
Microsetella norvegica (Boeck).

M. rosea Dana.
Clytemnestra rostrata (Brady).
C. scutellata Dana.
Ægisthus aculeatus Giesbr.
Æ. mucronatus Giesbr.
Pontœciella abyssicola (T. Scott).

From this and the preceding list together we have records of 52 Indo-Pacific species from the west coast of Europe.

I have been able to collate records of 120 epiplanktonic species that occur in the Mediterranean Sea (*vide* Giesbrecht (1892), Sars (1907), Steuer (1910), Früchtl (1920), Pesta (1920) and Rose (1934). (Pesta gives a number of references to other papers that deal with this region.) Of these species the following are known from the Indo-Pacific region :

Nannocalanus minor (Claus).
Eucalanus crassus Giesbr.
E. monachus Giesbr.
Mecynocera clausi Thompson.
Paracalanus aculeatus Giesbr.
P. nanus Sars.
P. parvus (Claus).
? *P. pygmæus.* (Claus).
Calocalanus pavo (Dana).
C. plumulosus (Claus).
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
Ctenocalanus vanus Giesbr.
Euchæta acuta Giesbr.
E. hebes Giesbr.
E. marina (Prestand.).
E. media Giesbr.
Scolecithrix danæ (Lubb.).
Scolecithricella bradyi (Giesbr.).
S. dentata (Giesbr.).
S. ovata Farran.
S. tenuiserrata (Giesbr.).
Centropages auklandicus Krämer.
C. bradyi Wheeler.
C. kröyeri Giesbr.
C. violaceus Brady.
Temora longicornis Baird.
T. stylifera (Dana).
Lucicutia flavicornis (Claus).
Pseudocyclops umbraticus Giesbr.
Candacia æthiopica Dana.
C. bipinnata Giesbr.

C. bispinosa Claus.
C. longimana Claus.
C. pectinata Brady (= *armata* Boeck).
C. simplex Giesbr.
C. tenuimana Giesbr.
C. varicans Giesbr.
Labidocera acutifrons (Dana).
L. kröyeri (Brady).
L. wollastoni (Lubb.).
Pontellopsis regalis (Dana).
P. villosa Brady.
Pontellina plumata Dana.
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*Planktacartia*) *danæ* Giesbr.
A. (*P.*) *negligens* Dana.
Oithona brevicornis Giesbr.
O. atlantica Farran.
O. linearis Giesbr. (? = *setigera* Dana).
O. nana Giesbr.
O. plumifera Baird.
O. robusta Giesbr.
O. setigera Dana.
O. similis Claus.
Oncæa conifera Giesbr.
O. dentipes Giesbr.
O. media Giesbr.
O. mediterranea Claus.
O. minuta Giesbr.
O. subtilis Giesbr.
O. venusta Philippi.
Lubbockia squillimana Claus.
Pontœciella abyssicola (T. Scott).
Corycæus (*Corycæus*) *clausi* F. Dahl.
C. (*C.*) *crassiusculus* Dana.
C. (*C.*) *speciosus* Dana.
C. (*Agetes*) *flaccus* Giesbr.
C. (*A.*) *limbatus* Brady.
C. (*A.*) *typicus* Kröyer.
C. (*Urocorycæus*) *furcifer* Claus.
C. (*U.*) *lautus* Dana.
C. (*Onychocorycæus*) *catus* F. Dahl.
C. (*O.*) *giesbrechti* F. Dahl.
C. (*O.*) *latus* Dana.
C. (*O.*) *obtusus* Dana.
C. (*O.*) *ovalis* Claus
? *C.* (*Corycella*) *carinatus* Giesbr

C. (*C.*) *curtus* Farran.
C. (*C.*) *rostratus* Claus.
Corina granulosa Giesbr. (= *Vettoria g.* (Giesbr.)).
Sapphirina angusta Dana.
S. auronitens Claus—*sinuicauda* Brady.
S. bicuspidata Giesbr.
S. lactens Giesbr.
S. maculosa Giesbr.
S. metallina Dana.
S. nigromaculata Claus.
S. iris Dana.
S. opalina Dana—*darwini* Haeckel.
S. ovatolanceolata Dana—*gemma* Dana.
? *S. scarlata* Giesbr.
? *S. stellata* Giesbr.
Copilia mediterranea (Claus).
C. mirabilis Dana.
C. quadrata Dana.
C. vitrea (Haeckel).
Ectinosoma melaniceps Boeck.
Microsetella norvegica (Boeck).
M. rosea Dana.
Euterpina acutifrons (Dana).
Macrosetella gracilis (Dana).
Clytemnestra scutellata Dana.
C. rostrata (Brady).

The occurrence of four of the above species in the Mediterranean Sea appears to be open to doubt, but in this area no less than 103 Indo-Pacific species, constituting about 86 per cent. of the planktonic population, are known to be present. In addition to these Indo-Pacific species some 12 or 14 other species, that appear to have had their origin in the Atlantic Ocean, have also been recorded, namely:

Calanus finmarchicus Gunn.
? *Centropages chierchiæ* Giesbr.
C. hamatus (Lillj.).
C. typicus Kröyer.
Isias clavipes Boeck.
Diaixis pygmæa T. Scott.
Pontella atlantica (M. E.).
P. lobiancoi Canu.
P. mediterranea Claus.
Anomalocera patersoni Templ.
Parapontella brevicornis (Lubb.).
? *Paracartia dubia* (T. Scott).
Corycæus (*Ditrichocorycæus*) *anglicus* Lubb.
Oncæa tenella Sars.

A few other species that have been recorded from the Mediterranean Sea are well known boreal or Arctic forms, namely:

Ctenocalanus vanus Giesbr.,
Pseudocalanus elongatus (Boeck),
Xanthocalanus minor Giesbr.,
Cyclopina elegans T. Scott,
C. longicornis Boeck,
Ectinosoma neglectum Sars,

and it has been claimed that some, at least, of these represent a "relict" fauna from the last Glacial period. Pesta (1920, p. 484) and Rose (1920) both dissent from this view, and Rose has suggested that *Pseudocalanus elongatus* (Boeck) and, in all probability, *Temora longicornis* Baird are carried into the Mediterranean Sea by the current that flows through the Strait of Gibraltar; the claim that *Temora longicornis* is a boreal or Arctic species overlooks the fact that this species has been recorded from the south-west Pacific Ocean, the Indian Ocean and the tropical region of the Atlantic Ocean. The two species of *Cyclopina* are known from the British Isles and the coast of Norway, and *C. longicornis* Boeck occurs also in Arctic waters.

Several species, some ten in number, appear to have had their origin in the Mediterranean Sea or its offshoot the Black Sea, namely:

Euchæta trunculosa Pesta (? a young stage),
Centropages ponticus Karawiew,
Labidocera brunescens (Czern.),
Stephus gyrans Giesbr.,
Acartia (*Hypoacartia*) *adriatica* Steuer,
A. (*Acanthacartia*) *italica* Steuer,
A. (*Paracartia*) *latisetosa* (Kriczagin),
Corycæus (*Ditrichocorycæus*) *brehmi* Steuer,
Ratania flava Giesbr.,
Cyclopina esilis Brian,

and to these should, perhaps, be added *Centropages chierchiæ* Giesbr., which Farran has suggested is a Mediterranean species. Ekman (1935, p. 423) has called attention to the difference that is to be found in the fauna of the eastern and western basins of the Mediterranean Sea, the latter being in general richer than the former; as a possible cause of this he notes that the eastern, and especially the south-eastern region of the Mediterranean is warmer and has a higher salinity than the western area.*

Schott (1928) has reviewed our knowledge of the currents from the Atlantic Ocean into the Mediterranean Sea through the Strait of Gibraltar, and he shows that there is, at almost all times, an inflowing current from the Atlantic Ocean, which is, owing to the effect of the earth's rotation, stronger on the African side than on the European; he also notes that the strength of the current will vary with the wind, a strong west wind causing an increase in the current, while a strong east wind may succeed in stopping it altogether. Most of the Indo-Pacific species that have been found in the Mediterranean Sea, and those that had their origin in the Atlantic Ocean, can have been swept into the Mediterranean

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* He also calls attention to the work of Thomsen (1931), who showed that the Mediterranean Sea as a whole, and the eastern region in particular, is markedly deficient in nitrates and phosphates.

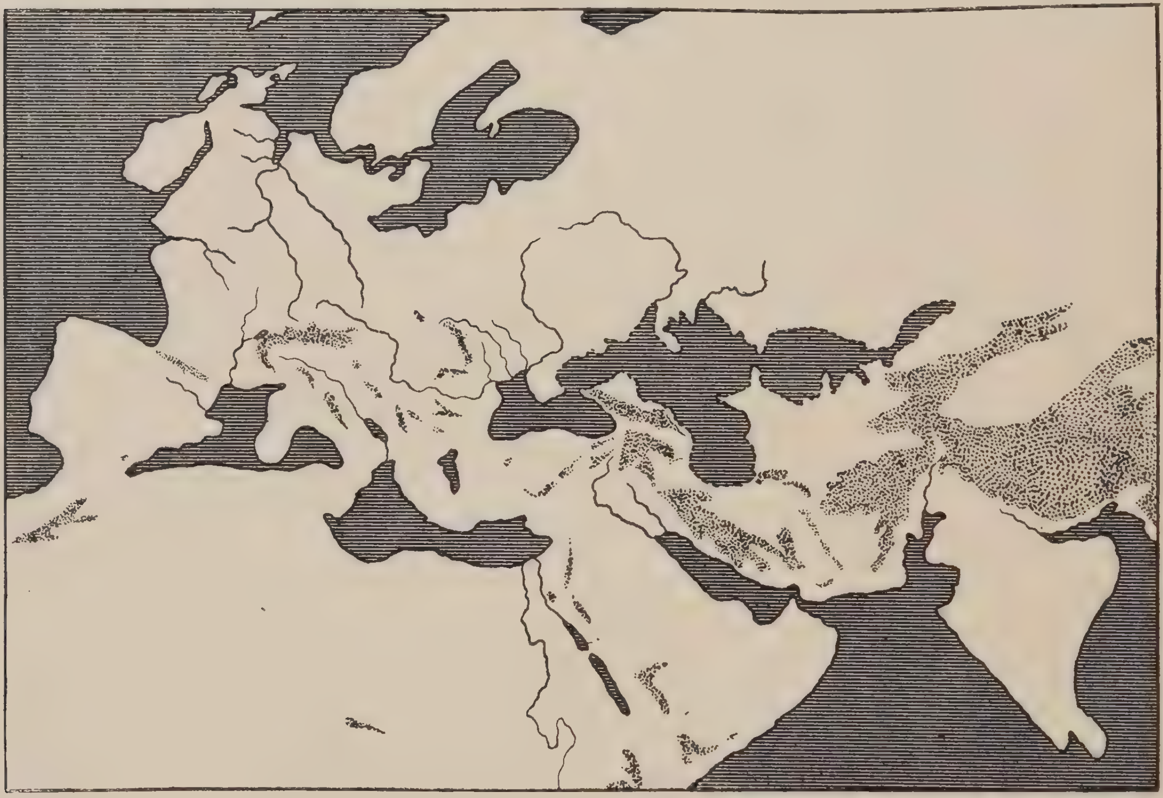
Sea by this current from the Atlantic; indeed it seems possible, or even probable, that this transference is still going on, for Rose (1929) has pointed out that at the present time several species appear to be mainly confined to the western area and are but rarely taken in the eastern region. Such species are—

Calocalanus styliremis Giesbr.
Centropages violaceus Brady.
Isias clavipes Boeck.
Pseudocalanus elongatus (Boeck).
Temora longicornis Baird.
Candacia æthiopica Dana.
C. varicans Giesbr.
Labidocera kröyeri (Brady).
Parapontella brevicornis (Lubb.).
Pontellopsis regalis (Dana).
Acartia (*Planktacartia*) *danæ* Giesbr.

It seems probable that these have been swept in through the Strait of Gibraltar, but have not as yet permanently established themselves in the eastern part of the Mediterranean.

In a few instances the known distribution is markedly discontinuous; *Centropages auklandicus* Krämer is at present known only from the south-west Pacific and the Mediterranean regions. *Oithona hebes* Giesbr. has been recorded from the Caribbean Sea, the East Pacific area and the Mediterranean Sea; *Oncæa dentipes* Giesbr. has been taken in both east and south-west Pacific areas and in the Mediterranean Sea; and finally *Centropages kröyeri* Giesbr., *Candacia tenuimana* Giesbr., *Vettoria granulosa* (Giesbr.) and *Pontœciella abyssicola* (T. Scott) are known from the Indo-Pacific region, the Mediterranean Sea and the Atlantic in the Gulf of Guinea. It is possible that all these may be "relict" species that originally attained their present distribution through the Tethys Sea in early Tertiary times, but this view takes no cognizance of the possible changes that occurred in the Mediterranean region during the last Glacial period.

The geological history of this region has been summarized by Munro Fox (1929, p. 844) as follows: "In Tertiary times the present Red Sea was a branch of the Mediterranean, unconnected with the Indian Ocean. Later, a southern water connection was effected, and the Red Sea then harboured a mixed Mediterranean and Indian Ocean fauna. Next the Red Sea became cut off from the Mediterranean by the Isthmus of Suez. This is composed of Quaternary deposits, containing the remains of marine faunas to the north and south and of a fresh-water fauna in the centre." Fuchs (1881) and Keller (1882) have both reviewed our knowledge of the conditions that existed in this area at the beginning of the Quaternary, and they have shown that in the Pleistocene the Mediterranean Sea extended southwards over the region of the Suez Canal as far as Lake Timsah. Lake Timsah and the region round it seems to have been occupied by a fresh-water area that was connected with the Nile River, while the Red Sea extended northwards as far as the Bitter Lakes. Steinitz (1929) has, however, again reviewed our knowledge, and he has reached the conclusion that the so-called fresh-water area round Lake Timsah was in reality an estuarine region in which the surface water was fresh, but that beneath this marine conditions persisted, so that there was thus a through channel for marine organisms; and in his opinion in Quaternary times immigration from the Red Sea into the Mediterranean Sea across the Suez isthmus was as great as, or even greater than, the influx from the Atlantic Ocean through the Strait of Gibraltar. None of these authors, however, takes account of the changes that in all probability took place in Pleistocene times during the last Glacial period. There is a considerable body of evidence that indicates that during the Glacial epoch there was a change in the relative levels of sea and land, partly as a result of the lowering of the sea level and partly by elevation of the land. Zeuner (1945) has recently reviewed our knowledge of the extent to which the sea-level fell during the last Glacial period as a result of the ice formation, and he shows that there was a succession of fluctuations during the period. Estimates of the amount of maximum lowering of sea-level vary from 90 to 200 m. These changes resulted in the formation of land isthmuses between Europe and Africa; the most westerly of these was situated where the Strait of Gibraltar now lies, and the second ran from Tunis through Malta and Sicily to Italy, while possibly a third isthmus connected Asia Minor with the Balkan Peninsula (*vide* Text fig. 87). The evidence for the existence of the Sicilian bridge is clearly given by Sir Arthur Keith (1929, p. 342 *et seq.*). If these changes actually took place, this interruption of the continuity of the Atlantic Ocean and Mediterranean Sea must have resulted in the formation of two separate lakes, entirely unconnected with either the Indo-Pacific or Atlantic region. Of the two Mediterranean lakes the eastern would have been the fresher, since it was fed by the Nile, the " Adriatic " river, and perhaps by a river that carried away the outflow from the Central Asiatic Lake that then existed. As Wells (1930) has pointed out, " When the Mediterranean was cut off from the Atlantic Ocean



Text-fig. 87.—The Mediterranean Region during the last Glacial Period. (From H. G. Wells.)

and the Black Sea it must have been a shrinking sea, with its waters sinking to a much lower level than that of the ocean outside. This is the case of the Caspian Sea to-day. Still more so is it the case with the Dead Sea." Similarly, the separation of the Red Sea from both the Mediterranean Sea and the Indian Ocean by the relative elevation of the "sill" that now extends from Arabia through the Hanish Islands and Jebel Zukheir to Africa, and which now lies at a depth of only about 100 m., must have resulted in the almost complete disappearance of the Red Sea as it exists to-day and its reduction to two small inland lakes that were in all probability hypersaline. Under such changes as these it is difficult to suppose that anything of the marine fauna can possibly have survived, and the original fauna of the Tethys Sea that was derived from the Indo-Pacific region must have disappeared. At the close of the Glacial Period, when the sea-level again rose, and perhaps also the land sank, so that the Strait of Gibraltar at the one end and the Strait of Bab-el-Mendeb at the other again permitted the influx of oceanic water, a marine fauna will have been swept in from the Atlantic Ocean to the Mediterranean Sea and from the Indian Ocean to the Red Sea. Among the immigrants from the Atlantic Ocean to the Mediterranean Sea a number of Atlantic species will have been carried in, and with these will have gone some of those that formerly inhabited the whole length of the Tethys Sea and were originally Indo-Pacific in origin; but some species of this latter group may not as yet have succeeded in penetrating back again from the North Atlantic into the Mediterranean Sea and in establishing themselves as permanent inhabitants, and the interruption between the Mediterranean Sea and the Red Sea that arose during the Quaternary will have prevented their ingress from the Indian Ocean; and thus their now discontinuous distribution can well be explained.

The Post-Glacial re-population of the Mediterranean Sea must have been in the main from the Atlantic Ocean and that of the Red Sea from the Indian Ocean, and until the construction of a canal between these two areas there can have been but little opportunity for the fauna of one region to pass to the other. Pesta (1920) has given a list of eight species that he seems to think have made their way into the Mediterranean Sea direct from the Indian Ocean and the Red Sea, and he claims that these species are absent from the Atlantic Ocean. The species that he names include both surface- and deep-dwelling forms; the surface-living species are:

Eucalanus monachus Giesbr.
Candacia longimana Claus.
C. tenuimana Giesbr.
C. simplex Giesbr.
Acartia (*Planktacartia*) *negligens* Dana.
Sapphirina auronitens Claus.

Every one of these has been recorded from the North Atlantic Ocean, and neither *Eucalanus monachus* Giesbr. nor *Candacia tenuimana* Giesbr. have as yet been reported from the Red Sea. Monro Fox (1927, p. 171, Table 20) considers that five species have entered the Suez Canal from the Mediterranean Sea end, namely:

Temora stylifera (Dana).
Corycœus (*Ditrichocorycœus*) *brehmi* Steuer.
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*Paracartia*) *latisetosa* (Kriczagin).
Centropages ponticus Karawiew.

He also think that *Oithona nana* Giesbr., *Oncæa media* Giesbr. and *Euterpina acutifrons* (Dana) have entered the canal from both ends. *Temora stylifera* (Dana) and *Acartia clausi* Giesbr. have both been recorded from the Gulf of Suez, so that, though the evidence at Monro Fox's disposal certainly seems to suggest a northern origin, it is possible that both these species may at some time or other have penetrated northwards from the Gulf. *Oithona nana* Giesbr. certainly seems to have entered the canal from both ends, since the forms at each end are different (*vide* Gurney, 1927, p. 159), and *Paracalanus parvus* (Claus) has almost certainly done so, since here again the forms at the two ends of the canal are different, f. *indicus* having entered from the Gulf of Suez and f. *borealis* from the Mediterranean Sea. Gurney (1927, p. 141) is of the opinion that two species, namely, *Canthocalanus pauper* Giesbr. and *Temora discaudata* Giesbr., " seem to afford evidence of a northward migration " through the Suez canal from the Red Sea, and as neither of these species have as yet been recorded from either the tropical or north temperate regions of the Atlantic Ocean, it is probable that he is right. On the other hand, Gurney (*loc. cit.*, p. 161) concludes that " the genus *Corycæus* provides strong evidence that the plankton species, which are common to the Red Sea and the Mediterranean, have not crossed the isthmus (of Suez). . . . It is obvious that the *Corycæus* of the Mediterranean have come from the west and not by the Isthmus." There thus seems to be very little evidence of any large transference of planktonic species from the Red Sea into the Mediterranean Sea through the Suez Canal under present conditions ; this seems to be a direct contradiction of what I showed to be the case among the weed-haunting Harpacticoida (*vide* Sewell, 1940a, p. 268), among which as many as 15 species seem to have passed from the Red Sea to the Mediterranean. The explanation of this difference is probably to be found in the different habitats of the two groups—the weed-haunting forms can be carried passively and rapidly through the canal in the weed on ship's bottoms, while the truly planktonic forms will have to survive the changes in temperature and salinity in the canal for several days, since it will take a succession of tides to sweep them through the whole distance, and hence have not reached the Mediterranean Sea in sufficiently large numbers to have been able to establish themselves in the new locality. Even where such a transference may have been accomplished, it might be masked by the presence in the Mediterranean Sea of other individuals of the same species that have been swept in from the Atlantic Ocean through the Strait of Gibraltar.

From the Bay of Biscay a branch of the North Atlantic Drift runs northwards across the mouth of the English Channel to the west of Ireland, where it is joined by another branch of the Drift, and the combined water mass sweeps round the north of Scotland and there divides into two streams, the one passing between Scotland and the Shetland Islands and turning south again on the east side of Scotland to sweep round the North Sea, and the other passing to the north of the Shetland Islands, continuing in its northeasterly course to flow along the coast of Norway to the Barents Sea. As we follow the current northwards we find a considerable falling off in the total number of species that have been recorded from any given area, though the number of individuals present may very considerably increase. From the coasts of the British Isles and the region to the west of Ireland some species of epiplanktonic Copepoda have been recorded (*vide* Brady (1878–81), Thompson (1887, 1895, 1896, 1897), T. Scott (1897 to 1905, a series of papers in the ' Annual Report of the Fishery Board for Scotland '), Farran (1903, 1905, 1908, 1920), Norman and T. Scott (1906), Ostenfeld (1906, 1916), Pearson (1906), Gurney (1907, 1931), Norman and Brady (1909), and Marine Biological Association (1931). Of the recorded species from this area the following 64 are Indo-Pacific species :

Eucalanus crassus Giesbr.
Rhincalanus cornutus Dana.
Mecynocera clausi Thompson.
Paracalanus parvus (Claus).
Calocalanus contractus Farran.*
C. pavo (Dana).
C. plumulosus (Claus).
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
C. paululus Farran.*
C. pergens Farran.*
Euchæta acuta Giesbr.
E. hebes Giesbr.
E. marina (Prestand.).
Scolecithrix danæ Lubb.
Scolecithricella bradyi Giesbr.
S. dentata Giesbr.
S. minor (Brady).
Temora longicornis Baird.
T. stylifera (Dana).
Temoropia mayumbæensis T. Scott.
Pseudocyclops obtusatus Brady and Robertson.
Lucicutia flavicornis (Claus).
Candacia pectinata Brady.
C. rotundata Wolfend. (= *inermis* Cleve).
C. tenuimana Giesbr.
C. varicans Giesbr.
Labidocera acuta (Dana).
L. kröyeri (Brady).
L. wollastoni (Lubb.).
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*A.*) *longiremis* (Lillj.).
A. (*Odontacartia*) *centrura* Giesbr.
Oithona atlantica Farran.
O. nana Giesbr.
O. plumifera Baird.
O. setigera Dana.
O. similis Claus.
Paroithona parvula Farran.
Oncæa conifera Giesbr.
O. media Giesbr.

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* This species was described by Farran (1926), from the Bay of Biscay. So far as I know, it has not yet been recorded from the Irish Coast or the British Isles.

O. mediterranea Claus.
O. minuta Giesbr.
O. notopus Giesbr.
O. ornata Giesbr.
O. subtilis Giesbr.
O. venusta Philippi.
Conæa rapax Giesbr.
Lubbockia aculeata Giesbr.
L. squillimana Claus.
Corycæus (*Corycæus*) *crassiusculus* Dana (= *venustus* Dana).
C. (*C.*) *speciosus* Dana.
Sapphirina iris Dana (= *salpæ* Claus).
Corina granulosa Giesbr. (= *Vettoria g.*).
Ectinosoma melaniceps Boeck.
E. normani T. and A. Scott.
Microsetella norvegica (Boeck).
M. rosea Dana.
Macrosetella gracilis Dana.
Euterpina acutifrons (Dana).
Clytemnestra rostrata (Brady).
C. scutellata Dana.
Ægisthus mucronatus Giesbr.
Æ. aculeatus Giesbr.

There appear to be considerable differences in the fauna of different regions of the British coasts. The main drift of Atlantic water at the present time appears to pass across the entrance to the English Channel and sweep up the west coast of Ireland ; and, as a result, by far the greater number of Indo-Pacific species have been taken in this region. I have been able to collate references to as many as 51 different Indo-Pacific species (*vide* Brady and Robertson (1872), Brady (1878–81), Thompson (1896, 1897, 1903), Farran (1903, 1905), Pearson (1906)) :

**Eucalanus crassus* Giesbr.
**Rhincalanus cornutus* Dana.
**Mecynocera clausi* Thompson.
Paracalanus parvus (Claus).
**Calocalanus pavo* (Dana).
**C. styliremis* Giesbr.
Clausocalanus arcuicornis (Dana).
Euchæta acuta Giesbr.
E. marina (Prestand.).
**Scolecithrix danæ* Lubb.
**Scolecithricella dentata* Giesbr.
**S. bradyi* Giesbr.
**S. minor* (Brady).
Temora longicornis Baird.
T. stylifera (Dana).

Temoropia mayumbæensis T. Scott.
Pseudocyclops obtusatus Brady and Robertson.
**Lucicutia flavicornis* (Claus).
Candacia pectinata Brady.
**C. rotundata* Wolf.
**Labidocera kröyeri* (Brady).
L. wollastoni (Lubb.).
Acartia (*Acartiura*) *clausi* Giesbr.
**A.* (*Odontacartia*) *centrura* Giesbr.
Oithona nana Giesbr.
O. plumifera Baird.
O. similis Claus.
**Paroithona parvula* Farran.
**Oncæa conifera* Giesbr.
**O. media* Giesbr.
O. mediterranea Claus.
O. minuta Giesbr.
**O. notopus* Giesbr.
O. ornata Giesbr.
O. subtilis Giesbr.
O. venutas Philippi.
**Conæa rapax* Giesbr.
Corycæus (*Corycæus*) *crassiusculus* Dana (as *venustus* Dana).
**C.* (*C.*) *speciosus* Dana.
**Sapphirina iris* Dana (as *salpæ* (Claus)).
Ectinosoma melaniceps Boeck.
**Corina granulosa* Giesbr.
E. normani T. and A. Scott.
Microsetella norvegica (Boeck).
**M. rosea* Dana.
Euterpina acutifrons (Dana).
**Macrosetella gracilis* (Dana).
Clytemnestra rostrata (Brady).
**C. scutellata* Dana.
**Ægisthus mucronatus* Giesbr.
Æ. aculeatus Giesbr.

Of the above list of 51 species no less than 26, marked with an asterisk, have never, as yet, been recorded from the waters of the English Channel. From this latter region only 26 Indo-Pacific species have been recorded (*vide* Norman and T. Scott (1906), Ostenfeld (1906), and Marine Biological Association (1931)), namely :

Paracalanus parvus (Claus).
Clausocalanus arcuicornis (Dana).
†*Euchæta hebes* Giesbr.
Temora longicornis Baird.
T. stylifera (Dana).

Pseudocalanus obtusatus Brady and Robertson.
Candacia pectinata Brady.
Labidocera wollastoni (Lubb.).
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*A.*) *longiremis* (Lillj.).
Oithona nana Giesbr.
O. plumifera Baird.
O. similis Claus.
Oncæa mediterranea Claus.
O. minuta Giesbr.
O. ornata Giesbr.
O. subtilis Giesbr.
O. venusta Philippi.
†*Lubbockia aculeata* Giesbr.
†*L. squillimana* Claus.
Corycæus (*Corycæus*) *crassiusculus* Dana (as *venustus* Dana).
Ectinosoma melaniceps Boeck.
E. normani T. and A. Scott.
Euterpina acutifrons (Dana).
Microsetella norvegica (Boeck).
Clytemnestra rostrata (Brady).

Of the above, three have not been recorded from the Irish coast; these are marked with a † in the above list.

Farran (1920, p. 22) remarks, " The records of *Euchæta hebes* require special mention. This species is a regular inhabitant of the Atlantic Drift off the mouth of the English Channel, or, at any rate, that part of it which flows past Ushant, and might be expected to occur frequently on the west coast of Ireland. It has, however, not yet been met with in any of the numerous hauls of the mesoplankton trawl made to the W. and S.W. of Ireland by the Department's steamer, and the single records from T.III and T.IV are the only ones known to me from W. of 10° long. This seems to indicate that the 70 mile Fastnet station, where it has occurred on three occasions, is at times flooded by water from off the mouth of the English Channel with its rather peculiar admixture of neritic and oceanic forms, and gives further support to the theory . . . of a cyclonic circulation of the water south of Ireland." The comparative paucity of Indo-Pacific species in the English Channel is in all probability correlated with the hydrographic conditions that pertain in the area to the immediate west, and especially with the poor influx of oceanic and North Atlantic Drift water into the Channel. As Kemp (1939) has pointed out, Matthews, Harvey and others have shown that to the south of Ireland there is an extensive cyclonic movement of water that greatly influences the conditions off the entrance to the Channel, and Russell (1938, p. 415) points out that " this swirl varies in extent and position; at times it appears to block the mouth of the Channel and at others it apparently retreats farther north, thus laying the Channel mouth open to more oceanic water from the south and south-west." The amount of influx of oceanic water may thus vary considerably in different years, and it appears to have been much reduced in recent times. Kemp (1939) has also called attention to the fact that in recent times there has been a change in the temperature of the sea-water in the north Atlantic region between Greenland and Bear Island, and that this has resulted in a change in the fauna of both the British Isles and Iceland. Such a rise of temperature would facilitate the transport of Indo-Pacific warm-water species into northern latitudes. (For further references to this subject I must refer the reader to Kemp's paper.) It is well known that variations in the temperature and salinity of the water off the coast of Europe are frequently experienced. According to the "transgression" theory of le Danois (1934) there is a periodic expansion of the warmer water of the North Atlantic; on the other hand, Iselin (1938) attributes these changes to alterations in the strength of the Gulf Stream, and he points out that a decrease in strength will be accompanied by a discharge of warm-water towards the north-east, and that "there is reason to believe that the warm saline water which from time to time seems to invade the European Coastal Areas arises more as a tongue than a current." Whatever the fundamental cause of these variations may be, there can be no doubt that such a movement of warm water will carry with it the corresponding fauna; as Bigelow (1931) has pointed out, "perhaps the best known example of broad scale transport to unfavourable regions is that of tropical pelagic organisms to fatally high latitudes by the agency of the Gulf Stream. And every gradation is to be seen in this respect, from sporadic drift of occasional individuals, far outside their normal ranges, to the opposite extreme, where a supply is so constantly brought from some far-off source that a permanent community is mechanically maintained in parts of the sea, where the species in question cannot reproduce itself."

As we pass northwards from the coast of Ireland to the north coast of Scotland and the neighbouring islands, Orkneys, Shetlands and Faroes, there seems to be a disappearance of quite a large number of species; and so far no specimens of any of the following species have been recorded from this northern region:

Mecynocera clausi Thompson.
Calocalanus pavo (Dana).
C. styliremis Giesbr.
Clausocalanus arcuicornis (Dana).
Scolecithricella dentata Giesbr.
Temora stylifera (Dana).
Labidocera kröyeri (Brady).
Temoropia mayumbæensis T. Scott.
Oncæa conifera Giesbr.
O. ornata Giesbr.
O. venusta Philippi.
Conæa rapax Giesbr.
Corina granulosa Giesbr.
Corycæus (Corycæus) crassiusculus Dana.
C. (C.) speciosus Dana.

Those species that have managed to survive up to this point may from now on take one of two routes: they may be carried either towards the north-east and so reach the North Sea and the coast of Norway, or they may be swept to the north-west towards Iceland and the coast of Greenland, and thence southwards again in the Labrador Current to the east coast of North America.

Taking the north-easterly current first, Wolfenden (1902, 1904) has recorded a number of species from the Faroe-Iceland Channel, and of these as many as 12 are known from the Indo-Pacific region, namely :

Rhincalanus cornutus Dana.
Paracalanus parvus (Claus).
Eucalanus crassus Giesbr.
Euchæta marina (Prestand.).
Scolecithricella minor (Brady).
Lucicutia flavicornis (Claus).
Candacia pectinata Brady (= *armata* Boeck).
Acartia (*Acartiura*) *clausi* Giesbr.
Oithona similis Claus (= *spinifrons* Boeck).
Oncœa mediterranea Claus.
O. subtilis Giesbr.
Microsetella norvegica (Boeck).

Other species that will probably be recorded sooner or later from this area, since they are already known to occur either in the North Sea or off the coast of Norway, are—

Pseudocyclops obtusatus Brady and Robertson.
Labidocera wollastoni (Lubb.).
Oithona plumifera Baird.*
O. nana Giesbr.
Paroithona parvula Farran.
Oncœa minuta Giesbr.
O. notopus Giesbr.
Sapphirina iris Dana.
Ectinosoma melaniceps Boeck.
Clytemnestra scutellata Dana.

A study of the surface currents shows how easily species living on the north coast of Scotland can be swept either into the North Sea and so reach the entrance to the Baltic Sea, or else pass direct to the coast of Norway. Records of the occurrence of species of Copepoda on the east coast of Scotland and England and in the North Sea have been made by Brady (1872), Timm (1894), T. Scott (1900, 1902), Norman and Brady (1909) and Pesta (1928). T. Scott (1902) has noted the occurrence on the north and east of Scotland of *Eucalanus crassus* Giesbr., and he remarks that this species " has on several occasions been taken on the Moray Firth. . . . Its occasional occurrence in the Moray Firth may therefore be owing to the action of currents passing round the north of Scotland into the North Sea. I have lately met with what looks like a southward extension of the distribution of the species on the east of Scotland, several specimens having been obtained in a tow-net gathering of Crustacea collected off Aberdeen, on November 11, 1901. This is the first time I have met with *Eucalanus crassus* so far south on the east coast." The species has been recorded from the North Sea in 1903 by Ostenfeld (1906).

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* The occurrence of *Oithona plumifera* Baird, as far north as the Faroe Channel is open to doubt : it is possible that the examples recorded from the North Sea and the coast of Norway should be referred to *Oithona atlantica* Farran.

The gradual elimination of Indo-Pacific species as one passes northwards from the tropics into cold water appears to have rendered possible the evolution of a number of new species and even of new genera, and the following have been recorded from the region of the British Isles :

†*Calanus helgolandicus* (Claus).
†*C. hyperboreus* Kröyer.
†*Amallophora brevicornis* Sars.
A. echinata Farran.
†*Diaixis hibernica* T. Scott.
†*Microcalanus pusillus* Sars.
Stephus fultoni T. and A. Scott.
†*S. minor* T. Scott.
†*S. scotti* Sars (= *gyrans* T. Scott, *non* Giesbr.).
†*Parastephus pallidus* Sars.
Pseudocyclopia caudatas T. Scott.
P. crassicornis T. Scott.
†*P. giesbrechti* Wolfend.
P. minor T. Scott.
†*P. stephoides* Thompson.
†*Eurytemora affinis* (Poppe) (= *clausi* Hoeck, *lacinulatus* (Sars)).
†*E. velox* (Lillj.).
†*Pseudocyclops crassiremis* Brady.
Mimocalanus cultrifer Farran.
M. nudus Farran.
Candacia gracillimana Farran.
Phænna zetlandica T. Scott.
†*Pseudophænna typica* Sars.
†*Acartia* (*Acartiura*) *discaudata* (Giesbr.).
†*A.* (*A.*) *longiremis* (Lillj.).
A. (*Acanthacartia*) *bifilosa* (Giesbr.).
†*A.* (*Paracartia*) *grani* Sars.
†*Paramisophria cluthæ* T. Scott.
Oithona pelagica Farran.
†*Cyclopina elegans* T. Scott.
†*C. gracilis* Claus.
†*C. longicornis* Boeck.
†*C. littoralis* Brady.
Oncæa exigua Farran.
O. obscura Farran.
Lubbockia brevis Farran.
Ægisthus atlanticus Wolfend.
Æ. spinulosus Farran.*

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* This species has been recorded by Wilson (1942) from the East Pacific area and from the North of Samoa. If this be correct, its distribution, like that of *Corycæus anglicus* Lubb., *Oncæa anglica* Brady, *O. similis* Sars, and *O. tenella* Sars, may perhaps be explainable on the grounds of the existence in Tertiary times of the channel across Central America (*vide supra*, p. 406).

Other species that seem to have had their origin in the tropical or temperate regions of the North Atlantic Ocean can have been swept eastward by the Gulf Stream and the North Atlantic Drift, and so may make their appearance on the coast of the British Isles. The following species have now been recorded :

Centropages chierchiæ Giesbr.
†*C. hamatus* (Lillj.).
†*C. typicus* Kröyer.
†*Isias clavipes* Boeck.
†*Anomalocera patersoni* Templ.
Pontella lobiancoi (Canu).
†*Parapontella brevicornis* (Lubb.).
†*Corycæus* (*Ditrichocorycæus*) *anglicus* Lubb.
†?*C.* (*Corycella*) *rostratus* Claus.*
†*Halithalestris krohni*.

In the south-east region of the North Sea the following Indo-Pacific species have been recorded (*vide* Timm, 1894 ; Ostenfeld, 1906 and 1916 · Pesta, 1928 ; and Wilson, 1942) :

Nannocalanus minor (Claus).
Paracalanus parvus (Claus).
Temora longicornis O. F. Müll.
Candacia pectinata Brady (= *armata* Boeck).
Labidocera wollastoni (Lubb.).
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*A.*) *longiremis* (Lillj.).
Oithona plumifera Baird (? = *atlantica* Farran).
O. nana Giesbr.
? *O. setigera* Dana.
O. similis Claus.
Oncæa conifera Giesbr.
O. subtilis Giesbr.
Sapphirina iris Dana.
Microsetella norvegica (Boeck).
Euterpina acutifrons (Dana).

From the North Sea a certain number of species have succeeded in getting into the western end of the Baltic Sea through the Skagerrak and Kattegat (*vide* Giesbrecht, 1882 ; Möbius, 1884 and 1887 ; Ostenfeld, 1906 and 1916 ; Jakubisiak, 1933 ; and Kunz, 1935), though the rapid reduction in the inner regions of this inland sea of the salinity of the water has prevented many of them establishing themselves in the central and northern regions of the Baltic Sea. I give below a list of these species and have indicated by the letters S (Skagerrak), K (Kattegat) and B (Baltic Sea) the region to which they have been able to penetrate:

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* M. Dahl (1912) claims that this species is limited to the Atlantic Ocean and the Mediterranean Sea, and that the records of its occurrence in the Pacific and Indian Oceans is due to faulty identification. It has however, been recorded from the Pacific Ocean by Farran (1929) and Wilson (1942).

Paracalanus parvus (Claus)—S, K and B.
Scolecithricella minor (Brady)—S.
Temora longicornis (O. F. Müll.)—S, K and B.
Candacia pectinata Brady—S and K.
Labidocera wollastoni (Lubb.)—S and K.
Acartia (*Acartiura*) *clausi* Giesbr.—S and K.
A. (*Acanthacartia*) *bifilosa* (Giesbr.)—S and K.
A. (*Acartiura*) *longiremis* (Lillj.)—S, K and B.
A. (*Acanthacartia*) *tonsa* Dana—S, K and B.
Oithona nana Giesbr.—S and K.
O. plumifera Baird—S and K.
O. similis Claus—S, K and B.
Oncæa conifera Giesbr.—S.
O. minuta Giesbr.—S.
O. subtilis Giesbr.—S.
Microsetella norvegica (Boeck)—S, K and B.
M. rosea Dana—K.
Euterpina acutifrons (Dana)—S.

All of the above species have been recorded from the Indo-Pacific region. In addition several Atlantic Ocean or British species have also been carried in, namely:

Calanus finmarchicus Gunn—S and K.
C. hyperboreus Kröyer—S.
Microcalanus pusillus Sars—S and K.
Pseudocalanus elongatus Boeck—S, K and B.
Centropages hamatus (Lillj.)—S, K and B.
C. typicus Kröyer—S and K.
Isias clavipes Boeck—S.
Eurytemora affinis (Poppe)—S.
Anomalocera patersoni Templ.—S and K.
Acartia (*Acartiura*) *discaudata* (Giesbr.)—S, K and B.
Corycæus (*Ditrichocorycæus*) *anglicus* Lubb.—S and K.
Cyclopina gracilis Claus—B.

I have (*vide supra*, p. 483) given a list of those species that appear to have their origin in the North Atlantic Ocean or round the coasts of the British Isles; if these species follow the same dispersal routes that I have already indicated for the Indo-Pacific species, we should expect to find many, if not most of them on the coast of Norway, and as many as 29 of these species, which I have indicated in the lists by a †, have been recorded from Norwegian waters.

Our knowledge of the Copepoda of Norway is very extensive, thanks to the work of G. O. Sars (1901–03, 1903–11, 1913–18 and 1919–21). Some 61 species have been recorded from the epiplankton, and of these the following are known to be Indo-Pacific forms:

Paracalanus parvus (Claus).
**Scolecithricella minor* (Brady).
**Pseudocyclops obtusatus* Brady and Robertson.
**Temora longicornis* Baird.
**Candacia pectinata* Brady (= *armata* Boeck).
**Labidocera wollastoni* (Lubb.).
**Acartia* (*Acartiura*) *clausi* Giesbr.
**A.* (*A.*) *longiremis* (Lillj.).
**Oithona atlantica* Farran (= *spinirostris* Claus).
**O. plumifera* Baird (? = *atlantica* Farran).
**O. similis* Claus (= *helgolandica* Claus).
Paroithona parvula Farran.
? **Oncæa conifera* Giesbr.
**O. minuta* Giesbr.
**O. notopus* Giesbr.
Sapphirina iris Dana.
**Ectinosoma melaniceps* Boeck.
E. normani T. and A. Scott.
**Microsetella norvegica* (Boeck).
Euterpina acutifrons (Dana).
Clytemnestra scutellata Dana.

A number of these species have survived even colder conditions, and have been recorded from Arctic waters (*vide* T. Scott, 1899; T. and A. Scott, 1901; Mrazek, 1902; Linko, 1907; and Farran, 1936*b*); these are indicated in the above list by an asterisk. To the list of Indo-Pacific species that have been taken in Arctic waters must be added *Oncæa mediterranea* Giesbr. (*vide* T. Scott, 1899, and Mrazek, 1902), though this species has, so far, not been recorded from the coast of Norway.

The proportion of Indo-Pacific species in these northern latitudes thus shows a marked fall, and they constitute only some 30 per cent. of the total number.

Several other surface-living Atlantic forms appear to have suffered the same fate, and have been swept northwards into Arctic regions, namely:

Euchæta wilsoni Jespersen,
Centropages hamatus (Lillj.),
Anomalocera patersoni Templ.,
? *Pontella atlantica* (M.E.),
Acartia (*Acanthacartia*) *bifilosa* (Giesbr.),
Tortanus discaudatus Thompson and A. Scott,
Cyclopina gracilis Claus,

and perhaps to these should be added—

Oncæa anglica Brady,
O. similis Sars,
O. tenella Sars,

which have been recorded from the northern regions of both the Atlantic and Pacific Oceans, and may have made their way from one to the other *via* the Arctic Ocean.

Those species that have been swept by the north-westerly branch of the North Atlantic Drift towards Iceland and Greenland and beyond must have been able to survive a considerable fall in the temperature of the water; even so we still find several species of Indo-Pacific origin in this area, and the following have been recorded by Jespersen (1934, 1939*a*, and 1939*b*), With (1915) and Wilson (1942):

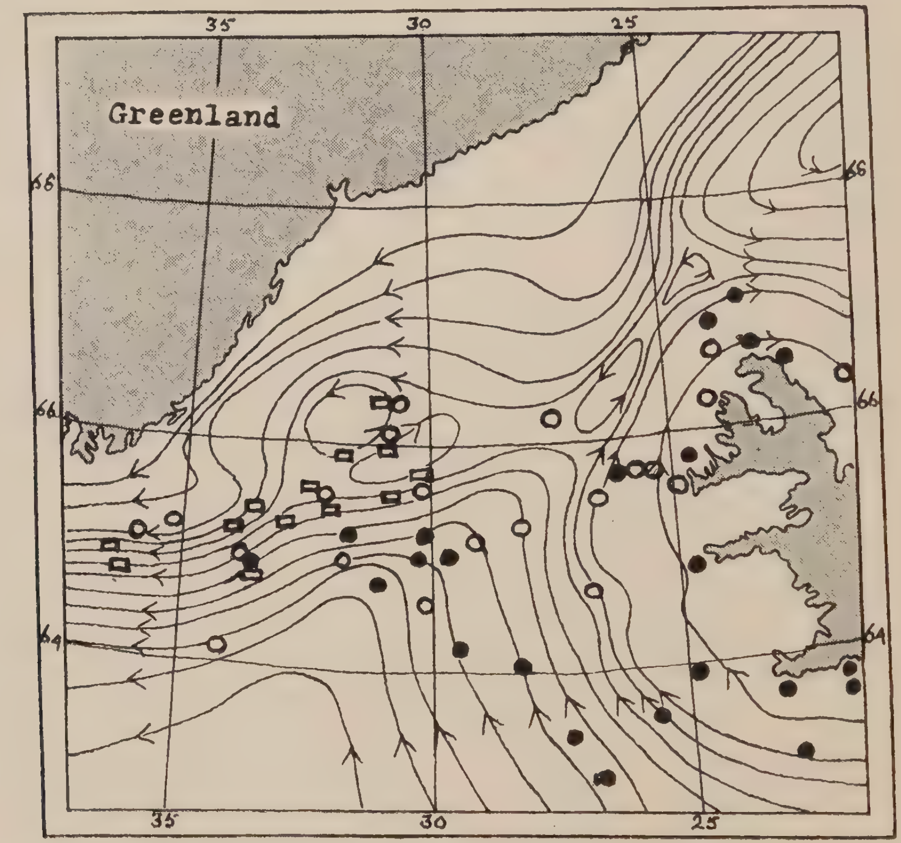
Paracalanus parvus (Claus).
Eucalanus crassus Giesbr.
Clausocalanus arcuicornis (Dana).
Euchæta acuta Giesbr.
E. hebes Giesbr.
Scolecithricella minor (Brady).
Temora longicornis (Müll.).
Acartia (*Acartiura*) *clausi* Giesbr.
Oithona atlantica Farran.
O. similis Claus.
Oncæa conifera Giesbr.
O. minuta Giesbr.
O. notopus Giesbr.
O. venusta Philippi.
Ectinosoma melaniceps Boeck.
Microsetella norvegica (Boeck).

All of these, with the exception of *Temora longicornis* (Müll.) and the species of *Oncæa*, are present on both east and west sides of Greenland. Jespersen (1940) and Wilson (1942) have recorded the following species from the area to the south of Iceland:

Calanus finmarchicus (Gunn.).
C. helgolandicus (Claus).
Nannocalanus minor (Claus).
Paracalanus parvus (Claus).
Clausocalanus arcuicornis (Dana).
Pseudocalanus minutus Kröyer.
Microcalanus pygmæus Sars.
Scolecithrix danæ (Lubb.).
Centropages hamatus (Lillj.).
Temora longicornis Baird.
Anomalocera pattersoni Templ.
Labidocera wollastoni (Lubb.).
Pontella lobiancoi Canu.
Acartia (*Acartiura*) *clausi* Giesbr.
A. (*Acanthacartia*) *bifilosa* (Giesbr.).
A. (*A.*) *longiremis* (Lillj.).
Oithona atlantica Farran.
O. nana Giesbr.
? *O. plumifera* Baird (? = *atlantica* Farran).
O. setigera Dana.
O. similis Claus.

Oncœa borealis Sars.
O. conifera Giesbr.
O. venusta Philippi.
Microsetella norvegica (Boeck).
Clytemnestra rostrata (Brady).

Jespersen (1934, p. 49) has noted that specimens of *Paracalanus parvus* were present in the area to the south-west of Iceland in the surface layer, but that in the Labrador Sea to the south of Davis Strait they were only taken in deeper water, when the nets were fished with 1000–2500 m. of wire out. He estimates that this length of wire corresponds to a depth of the net of about one-half to two-thirds this distance, namely, to depths of from 500 to 1670 m. Smith, Soule and Mosby (1937) have pointed out that the East Greenland Arctic Current and a western branch of the Irminger Current, on rounding Cape Farewell, are renamed the West Greenland Current, and that this flows northwards and then branches, part crossing Davis Strait ridge into Baffin Bay, and part flowing westward on the south side of Davis Strait ridge to join Arctic water that is flowing southwards out of Baffin Bay to produce the Labrador Current. They also show that the warm salty West Greenland water progressively sinks as it proceeds northwards and then westwards and finally southwards, spreading out as it goes to form the intermediate water of the Labrador Sea between



Text-fig. 88.—Chart of the Irminger Current (after Nansen), showing the position of Stations where certain Copepoda were captured. ● = *Scolecithricella minor* (Brady). ▭ = *Pseudocalanus minutus* (Kroyer). ○ = *Microsetella norvegica* (Boeck).

some 500 and 2000 m. depth. Such an admixture of water provides a reasonable explanation of the occurrence of *Paracalanus parvus* (Claus) in the Labrador Sea at the depths given above. A comparison of the occurrence of *Scolecithricella minor* (Brady) and *Microsetella norvegica* (Boeck) and the main course of the Irminger Current, as shown by Nansen (*vide* Text fig. 88) leaves little doubt that these species, like *Paracalanus parvus*, are swept westward into the Labrador Sea by the Irminger Current, whereas *Pseudocalanus minutus* Kröyer appears to be swept southwards from the Arctic region in the East Greenland Current.

From Baffin Bay along the North American Coast as far south as Chesapeake Bay, in lat. 38° N., a belt of cold water separates the coast from the warm water of the Gulf Stream and the North Atlantic Drift. Passing out of Baffin Bay is the Labrador Current, but it is doubtful whether this actually reaches further south than the coast of Nova Scotia; beyond this in the region of the Gulf of Maine the cold water is probably derived from a different source. Bigelow (1924) remarks, "The low temperature of the surface water near shore, contrasted with the 'Gulf Stream' offshore and with the oceans as a whole at the latitude in question, naturally suggests a northern origin until analysed in relation to other factors. . . . The south-westerly drift that has been reported repeatedly along the coasts of the north-eastern United States and Nova Scotia argues in the same direction; so, also, the extension of a generally boreal fauna southward and westward as far as Cape Cod, with planktonic communities of this category spreading still farther in this direction in winter." Bigelow, however, maintains that the Labrador Current does not reach, much less skirt, the coast of North America from Nova Scotia southwards as a regular event. He attributes this cold water to the effect of melting of the ice from the Gulf of St. Lawrence: "it is to this cold band skirting Nova Scotia that the name 'Nova Scotia current' is applied. . . . During the spring a large volume of water enters the eastern side of the Gulf of Maine from this source." Thanks to the work of Wheeler (1900), Sharpe (1911), Sumner, Osburn and Cole (1911), Willey (1919, 1932), Fish (1925), Wilson (1932*a* and *b*), Bigelow and Sears (1939) and Nicholls (1940), we now possess considerable knowledge of the Copepod fauna of this coastal region. In all, some 85 species of Epiplanktonic Copepods have been recorded, and among these the following are known from the Indo-Pacific region:

Nannocalanus minor (Claus).
Undinula vulgaris (Dana).
Eucalanus crassus Giesbr.
E. monachus Giesbr.
Rhincalanus cornutus Dana f. *atlantica* Schmaus.
Mecynocera clausi Thompson.
**Paracalanus parvus* (Claus).
Calocalanus pavo (Dana).
C. plumulosus (Claus).
**Clausocalanus arcuicornis* (Dana).
Euchæta marina (Prestand.).
Scolecithrix danae (Lubb.).
**Scolecithricella minor* (Brady).
Centropages bradyi Wheeler.
C. violaceus Brady.

Temora longicornis Baird.
T. stylifera (Dana).
T. turbinata (Dana).
Candacia pectinata Brady (= *armata* Boeck).
C. pachydactyla Dana.
C. simplex Giesbr.
C. varicans Giesbr.
Labidocera acutifrons (Dana).
L. nerii (Kröyer).
Pontella securifer Brady.
P. spinipes Giesbr.
Pontellopsis regalis (Dana).
P. villosa Brady.
Pontellina plumata Dana.
**Acartia* (*Acartiura*) *clausi* Giesbr.
**A.* (*A.*) *longiremis* (Lillj.).
A. (*Acanthacartia*) *tonsa* Dana.
A. (*Planktacartia*) *danae* Giesbr.
**Oithona atlantica* Farran.
O. brevicornis Giesbr.
O. nana Giesbr.
O. plumifera Baird.
**O. similis* Claus.
Oncœa conifera Giesbr.
**O. minuta* Giesbr.
O. venusta Philippi.
Corycœus (*Corycœus*) *crassiusculus* Dana.
C. (*C.*) *speciosus* Dana.
C. (*Monocorycœus*) *robustus* Giesbr.
C. (*Agetes*) *flaccus* Giesbr.
C. (*Ditrichocorycœus*) *lubbocki* Giesbr.
C. (*Corycella*) *carinatus* Giesbr.
C. (*C.*) *rostratus* Claus.
Sapphirina angusta Dana.
S. auronitens Claus—*sinuicauda* Brady.
S. nigromaculata Claus.
S. ovatolanceolata Dana—*gemma* Dana.
S. scarlata Giesbr.
Copilia mirabilis Dana.
**Microsetella norvegica* (Boeck).
M. rosea Dana.
Macrosetella gracilis (Dana).
M. oculata Sars.
Miracia efferata Dana.
Clytemnestra rostrata (Brady).
Ægisthus mucronatus Giesbr.

We thus find as many as 61 Indo-Pacific species, forming some 72 per cent. of the epiplanktonic population, in this cold belt. A few of these species, which I have indicated in the above list by means of an asterisk, may have been carried southward in the Labrador and Nova Scotia currents; and along these same currents certain boreal or even Arctic species appear to have been swept southward, such as—

Pseudocalanus minutus Kröyer.
Centropages hamatus (Lillj.).
C. typicus Kröyer.
Eurytemora affinis (Poppe).
E. herdmani Thompson and A. Scott.
Tortanus discaudatus Thompson and A. Scott.
Acartia (*Acartiura*) *discaudata* (Giesbr.).
A. (*Acanthacartia*) *bifilosa* (Giesbr.).
Oncæa borealis Sars.
Ectinosoma neglectum Sars.

It seems probable, however, that the great majority of warm-water species must have reached the coast by passing from the Gulf Stream across the sub-polar convergence zone into the cold water along the coastal belt.

Willey (1932) pointed out that a number of species, that had been recorded by T. Scott (1894) from the Gulf of Guinea, have also been taken in the Great Acadian Bight between Cape Cod and Cape Race, and he gives a list of 15 such species and contrasts the frequency with which they were taken in this region with the comparative rarity of 12 other species, which he terms " endemic " in the Gulf of Guinea. Unfortunately he has paid no attention to the depth at which these latter species normally live, so that in his list of so-called " endemic " species there are no less than 11, which are deep-dwellers and have been taken in either the Indian or Pacific Oceans or in both. Wilson (1932*b*) has noted that a number of species taken in the Chesapeake Bay area were found only in the outside oceanic region along the 100-fathom line, and Bigelow and Sears (1939) in their studies of the zoo-plankton of the American coast between Cape Cod and Chesapeake Bay have noted the occurrence of several tropical species, particularly in the off-shore zone in about 200 m. of water, and they attribute this to the occasional transgression of warm off-shore water; among the surface-living species that they cite as immigrants into the continental region from off-shore are the following:

Nannocalanus minor (Claus),
Undinula vulgaris (Dana),
Mecynocera clausi Thompson,
Scolecithrix danæ (Lubb.),
Centropages violaceus (Claus),
Candacia pectinata Brady (= *armata* Boeck),

and certain species of the genus *Sapphirina*. They also include a number of deep-dwelling species belonging to the genera *Eucalanus*, *Euchirella*, *Pleuromamma* and *Rhincalanus*.

A similar extension of the range of tropical species along the north-east coast of America is shown by the Algæ; Taylor (1937) has given a list of 14 species of tropical algæ found in this coastal region, but a study of his monograph shows that, in addition to these, there are 18 other species that appear to have reached the coast from the tropics, 22 warm water species that seem to have spread northwards from Florida, and 13 species that are known from Bermuda. The explanation of the occurrence of these warm-water and tropical species, whether animal or plant, along the American coast appears to lie in the mechanics of the Gulf Stream. Redfield (1936) has called attention to a paper by Rossby (1936), which points out that in the Gulf Stream there is an absorption of water on the right side of the Current that must be derived from the Antilles Current, which is itself a continuation of the North Equatorial Current, and a discharge of water on the left side into the coastal zone; hence, as Rossby points out (*loc. cit.*, p. 24), " Through this upstream absorption along the right edge combined with the downstream discharge of eddies along the left edge, water may be transferred across the current from the open ocean basin to the right into the limited body of water to the left of the current." Redfield points out that " Rossby's study suggests that the absorption of oceanic water into the Gulf Stream takes place chiefly south of the latitude of Chesapeake Bay; the discharge of this water at a lesser depth occurs from Cheapeake Bay to at least Nova Scotia." Although Redfield is concerned with the transfer of chemical nutrient substances dissolved in the water, such a movement must also carry with it some at least of the Zoo- and Phytoplankton, and it seems highly probable that the presence of so many tropical and warm-water species on this part of the North American coast, which is bathed by cold water coming down from the north-east, is to be accounted for in this way. Church (1937) has given an account of these extensions of Gulf Stream water, and states that " a warm mass will appear quite suddenly and spread over a fairly large area with great rapidity. . . . The trend of the isotherms shows the mass to be thumblike in shape. . . . The pattern is thus indicative of an eddy or whirl. . . . On the charts these water masses appear as offshoots from the warm water of the Gulf Stream"; and he draws attention to the fact that these water masses correspond to the " transgression" of Le Danois. Bigelow (1924, p. 836) has remarked that " small amounts of ' Gulf Stream ' water have long been known to drift inward towards the sector of coast line bounded on the east by Martha's Vineyard and on the west by Narragansett Bay, during most summers, bringing with them a typically tropical fauna of fishes, planktonic invertebrates and Gulf Weed (Sargassum)." This " migration" of warm-water species along the American coast has been noted by numerous observers, and Fish and Johnson (1937) have shown that even as far north as the Bay of Fundy and the Gulf of Maine " tropical communities enter the gulf sporadically during the summer, usually between April and September, and successive waves may be composed of quite different associations depending on the nature of the stock in the Gulf Stream at the time." There is, however, still another route by which a number of these " tropical" species can eventually reach the American coast; Iselin (1934) has drawn attention to the fact that, although the Gulf Stream is a warm water current, some at least of the water in it is derived from the Sub-Polar Antarctic intermediate water. The absorption of water from this cold stream must carry with it some of the plankton, and among the species that are common to the tropical warm water and the West Wind Drift and which could be carried northwards by the Sub-Polar Intermediate Current and so reach the American coast are the following species;

Nannocalanus minor (Claus),
Mecynocera clausi Thompson,
Paracalanus parvus (Claus),
Calocalanus pavo (Dana),
C. styliremis Giesbr.,
Clausocalanus arcuicornis (Dana),
Euchæta marina (Prestand.),
Scolecithricella minor (Brady),
Centropages violaceus (Claus),
Temora turbinata Dana,
Labidocera acutifrons (Dana),
Acartia (*Acartiura*) *clausi* Giesbr.,
A. (*Planktacartia*) *danæ* Giesbr.,
Oithona plumifera Baird,
O. similis Claus,
Oncæa conifera Giesbr.,
Corycæus (*Corycæus*) *speciosus* Dana,
C. (*Corycella*) *rostratus* Claus,
Sapphirina scarlata Giesbr.,
Microsetella norvegica (Boeck),
M. rosea Dana,
Macrosetella gracilis (Dana),
Clytemnestra rostrata (Brady),

and to these we may perhaps add *Drepanopus pectinatus* Brady, which has been recorded by Wilson (1942) in the "Carnegie" collection from lat. 44° 39′ N., long. 33° 06′ W., at 100 m. depth.

A few species appear to have had their origin in this region of the American coast, namely :

Pseudodiaptomus coronatus Williams.
Eurytemora americana Williams (= *E. transversalis* Campbell, *E. kieferi* Sumner).
E. herdmani Thompson and A. Scott.
Euchæta wilsoni Jespersen.
Labidocera æstiva Wheeler.
Pontella meadi Wheeler.
P. pennata Wilson.
Tortanus setacaudatus Williams.
Acartia forcipata Thompson and A. Scott.
Cyclopina agilis Wilson.
C. laurentica Nicholls.
C. vachoni Nicholls.

As, up to the present time, none of these species has been taken elsewhere, it seems justifiable to regard them as being endemic.

THE DISTRIBUTION OF THE MESO- AND BATHY-PLANKTONIC SPECIES.

Since the movement of the surface currents appears to provide an adequate explanation of the distribution of the plankton of the upper levels of the ocean, it would appear probable that the movement of the sub-surface masses of water will provide an equally adequate explanation of the distribution of those species that inhabit either the intermediate or bottom water ; and, furthermore, if, as we have seen, the surface water can be divided into biological regions owing to the differences in the plankton of the various surface currents, it is only reasonable to expect that we shall also find similar differences in the deeper currents. Our knowledge of the movements of the deep masses of water is still incomplete, but the recent work of the "Meteor" in the Atlantic Ocean, the "Discovery" in the Antarctic, the "Dana" and the "Mabahis" in the Indian Ocean and the "Carnegie" in the Pacific has added considerably to the achievements of previous expeditions, and has demonstrated at least the chief features of this circulation. In Chart II I have attempted to indicate the main lines along which the water masses move at different depths.

Hentschel (1929) has put forward the view that the distribution of the Oceanic Plankton in the upper levels is determined by two factors, namely, the supply of nutrient materials and the distribution of these by horizontal and vertical currents, and in consequence of this he claims that in each area the density of the deep-dwelling plankton corresponds to the quantity of organisms living on the surface. In this connection it must, however, be borne in mind that the distribution of the food-supply and the plankton in these deeper levels must follow the movement of the water in those levels and not the direction of the surface currents. Steuer (1931) also attempted to correlate the distribution of the plankton with that of the nutrient salts, especially the phosphates, in the surface water, and he has given a chart (*loc. cit.*, p. 469, fig. i) showing the distribution in the Atlantic Ocean of the two species of the genus *Rhincalanus*, namely, *R. nasutus* Giesbr. and *R. gigas* Brady. He claims that the distribution of the former species shows two maxima, one in the region of the Cape Verde Islands and the other off the west coast of Africa respectively. Hentschel (1937, p. 153), in an Appendix to Steuer's Report (1937) on the distribution of several genera in the South Atlantic Ocean, claims that the fertility of these two regions is due to the increased Nannoplankton content, and that this in turn can be attributed to upwelling water off the African coast. It seems to me that a rich food-supply in any given area can, at any rate in the main, only affect the total number of individuals that are living there and have but little effect on the number of species, though any upwelling current that brings with it an increased amount of nutrient material and so renders possible an increase in the Phytoplankton may also import species that are normally to be found in the deeper levels.

In many localities the composition of the planktonic fauna, and particularly of the Copepoda, has been attributed to local hydrographic conditions, and in this connection it must be borne in mind that the configuration of the sea-floor has a direct influence on the direction and extent of flow of the bottom currents, and it is more than probable that even the mid-water currents are to some extent indirectly influenced by the bottom topography.

Commencing with the Arctic fauna, Mrazek (1902) has noted that individual Arctic species of Copepods have been found to penetrate southwards into the sub-Arctic region—

for instance, on the Norwegian coast; and Lysholm and Nordgaard (1921) adopted "the conception of an intimate connection between currents and planktonic animals." Jespersen (1924) reached the same conclusion, and pointed out that a number of species that were previously considered to be Arctic "penetrate in reality far down into the Atlantic. It must, however, be stated as regards these that in the more southerly latitudes they are most often found in great depths where the temperature is low, whereas in the Arctic seas they are often found in the upper layers of water. The occurrence of such 'Arctic' copepods in the great depths in the central parts of the Atlantic must undoubtedly be ascribed to the cold bottom water which has conveyed the organisms from the Arctic areas." It is a matter of some difficulty to decide which species are to be considered as truly Arctic, since one is always faced with the possibility that species may have originated in the North Atlantic area and have been carried thence into northern waters. Lysholm and Nordgaard (1921) have pointed out that the Wyville-Thompson Ridge (550 m.), the Faroe-Iceland Ridge (500 m.) and the Iceland-Greenland Ridge (*ca.* 550 m.) form a barrier to the northward penetration of Atlantic species, and hence "we cannot expect to find Atlantic deep-sea forms in the Norwegian Sea, as the separating ridges are comparatively high, and cold water flows over these ridges into the Atlantic." Similarly Jespersen (1934) has pointed out that "the cold water in Baffin Bay undoubtedly forms a barrier against the penetration northwards of several species, but besides this the submarine ridge in the Davis Strait is so prominent that it must certainly prevent many pronounced deep water species from extending further north." It would thus appear probable that at least the great majority of species that have been taken in the Arctic Ocean have had their origin in these northern waters. Mrazek (1902) has given a list of those species which he believes to be true Arctic forms, and to this certain other species have been added (*vide* T. Scott, 1901, and Sars, 1909). It seems probable that the great majority of the following are true Arctic species:

**Calanus cristatus* Kröyer,
**C. finmarchicus* (Gunn.),
**C. hyperboreus* Kröyer,
**C. tonsus* Brady,
**Pseudocalanus elongatus* (Boeck) (*sensu lato*),
**Microcalanus pygmæus* Sars (= *pusillus* Sars),
**Ctenocalanus vanus* Giesbr.,
**Spinocalanus abyssalis* Giesbr. (= *longicornis* Sars),
**S. magnus* Wolfend. (= *spinosus* Farran),
S. schaudini Mrazek (? = *abyssalis* Giesbr.),
? **Ætideopsis multiserrata* Wolfend. (= *Chiridius nastus* With, *Ætideopsis rostrata* A. Scott *non* Sars),
Chiridius armatus Boeck,
C. modestus With,
**C. obtusifrons* Sars (= *Ch. armatus* Sars *non* Boeck),
**Bradyidius armatus* (Vanhöffen) (= *Undinopsis similis* Sars),
Drepanopsis bungei Sars,
Bradyetes brevis Farran,
Undinella oblonga Sars,

**Gaidius brevispinus* (Sars) (= *major* Wolfend.),
**G. tenuispinus* (Sars) (= *borealis* Wolfend.),
Undeuchæta spectabilis Sars,
Paraeuchæta farrani (With),
**P. glacialis* (Hansen),
**P. norvegica* (Boeck),
Scolecithrix römeri Mrazek,†
Neoscolecithrix farrani Smirnov,
**Xanthocalanus hirtipes* Vanhöffer (= *borealis* Sars),
X. propinquus Sars,
**Scaphocalanus brevicornis* (Sars) (= *gracilis* (Farran)),
**S. magnus* (T. Scott) (= *acrocephalus* Sars),
Eurytemora americana Williams (? = *thompsoni* Willey),
E. canadensis Marsh,
E. grimmi (Sars),
E. herdmani Thompson and A. Scott,
E. johanseni Willey (? = *pacifica* Sato),
E. raboti Richard,
E. tolli Rylov,
**Metridia longa* (Lubb.),
**Heterorhabdus norvegicus* (Boeck) (? = *abyssalis* Giesbr.),
**Haloptilus acutifrons* (Giesbr.),
**H. spiniceps* Sars,
**Augaptilus glacialis* Sars (= *zetesios* Wolfenden),
Temorites brevis Sars,
Limnocalanus grimaldii de Guerne,
L. macrurus Sars,
Centropages mcmurrichi Willey,
**Candacia norvegica* Boeck,
Paralabidocera amphitrite McMurrich,
Acartia tumida Willey,
Mormonilla polaris Sars,
Oncæa borealis Sars,

and perhaps to these should be added *Undeuchæta incisa* Esterly (*Pseudochirella superba* (With)), which has been taken in the Faroe-Iceland Channel, between Iceland and Greenland and off West Greenland.

In addition to the above, Farran (in Russell, 1935) gives *Acartia longiremis* (Lillj.) as Arctic and *Metridia lucens* Boeck, *Heterorhabdus compactus* Sars and *Candacia falcifera* Farran (= *magna* Sewell) as epiplanktonic Bipolar species, but I am inclined to regard the distribution of these species in northern waters as boreal-Atlantic rather than as truly Arctic; and according to Steuer (1923) *Acartia longiremis* is a North Atlantic boreal species, occurring off the Norwegian coast, in the Barents Sea, around Iceland, on the west coast of Greenland and in the Labrador Current, but Wilson (1932) records it in the Gulf of Maine and (1942) in the Sargasso Sea, the Caribbean region and in the Pacific Ocean north of Samoa.

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† According to Brady (1918, p. 23) this species is synonymous with *S. glacialis* Giesbrecht, from the Antarctic region; With (1915, p. 207) is "fairly convinced that it is identical with *Scolecithricella minor* (Brady)."

Of the above Arctic species some appear to be essentially epiplanktonic, while others are littoral or even fresh-water inhabitants ; but 33 species have been taken in deep water, and of these no less than 26, marked in the above list with an asterisk, have been carried southwards into the North Atlantic Ocean and some have got considerably further ; thus *Calanus finmarchicus* (Gunn.), *C. tonsus* Brady, *Pseudocalanus elongatus* (Boeck), *Microcalanus pygmæus* Sars, *Ctenocalanus vanus* Giesbr., *Spinocalanus abyssalis* Giesbr., *S. magnus* Wolfend., *Gaidius tenuispinus* (Sars), ? *Scolecithrix römeri* Mrazek, *Scaphocalanus magnus* (T. Scott) and *Metridia longa* (Lubb.) have reached the Sub-Antarctic and even Antarctic region. *Calanus finmarchicus* (Gunn.), *Spinocalanus magnus* Wolfend., *Bradyidius armatus* (Vanhöffen), *Gaidius tenuispinus* (Sars), *Metridia longa* (Lubb.), *Scaphocalanus magnus* (T. Scott), *Xanthocalanus hirtipes* Vanhöffen and *Haloptilus acutifrons* (Giesbr.) have been taken in the Indian Ocean, and to these should be added *Heterorhabdus norvegicus* (Boeck), if I am correct in regarding this species as identical with *H. abyssalis* Giesbr., and *Candacia norvegica* Boeck, which is represented in Indian waters by a variety, *tropica* Sewell. *Calanus finmarchicus* (Gunn.), *C. hyperboreus* Kröyer, *C. tonsus* Brady, *Pseudocalanus elongatus* (Boeck), *Microcalanus pygmæus* Sars, *Ctenocalanus vanus* Giesbr., *Spinocalanus abyssalis* Giesbr., *S. magnus* Wolfend., *Gaidius tenuispinus* (Sars), *Metridia longa* (Lubb.), *Haloptilus acutifrons* (Giesbr.), *H. spiniceps* (Giesbr.), *Scaphocalanus magnus* (T. Scott) and *Heterorhabdus norvegicus* (Boeck) (= *abyssalis* Giesbr.) have been taken in the North Pacific Ocean, and with the exception of *Calanus hyperboreus* Kröyer have been also recorded from the South Pacific, where yet another Arctic species, *Calanus tonsus* Brady, has been taken.

As Mrazek (1902) has pointed out, such evidence as we at present possess indicates that the true Arctic species have a circum-polar habitat, and this is also probably true of those North Atlantic species that have been carried into the Arctic regions and have been able to survive and reproduce in these northern latitudes. If this be conceded, we should expect to find that some of these Arctic species have been swept southwards through the Bering Strait into the north-western part of the Pacific Ocean by the Oya-sio Current, and this would account for the presence in the Japanese area of the following Arctic species, recorded by Marukawa (1921) and Tanaka (1937) :

Calanus cristatus Kröyer,
Pseudocalanus minutus Kröyer (= *elongatus* Boeck),
Microcalanus pygmæus Sars (= *pusillus* Sars),
Ctenocalanus vanus Giesbr.,
Spinocalanus abyssalis Giesbr.,
Gaidius tenuispinus Sars,
Metridia longa (Lubb.),

and those from the extreme north of the Pacific Ocean in the vicinity of the Aleutian Islands, recorded by Wilson (1942) :

Calanus cristatus Kröyer,
C. finmarchicus (Gunn.),
C. hyperboreus Kröyer,

Pseudocalanus minutus (Kröyer) (= *elongatus* Boeck),
Ætideus armatus Brady,
Gaidius tenuispinus (Sars),
Metridia longa (Lubb.),
Acartia longiremis (Lillj.),

and perhaps to these should be added *Drepanopsis* sp., recorded by Marukawa from Japanese waters, if this be the same species as *D. bungei* Sars.

The next mass of water to be considered arises in the Northern Hemisphere, and to a large extent fills the North Atlantic basins lying respectively to the west and east of the mid-Atlantic ridge. The main mass of this water originates by a sinking down of the surface water between lats. 20° and 60° N., and this is joined by a deep current of Arctic water that is flowing southward from Baffin's Bay through Davis Strait (*vide* Wüst, 1928); at first the main mass of this North Atlantic Intermediate water, in which it is possible to detect several different hydrographic strata, collects under the influence of the spin of the earth along the American coast, where it lies at a depth of 1500 down to 4000 m., the main stream being between 2000 and 3000 m. In about lat. 20° N. this great stream is still further augmented by a mass of water that has flowed in a deep current out of the Mediterranean Sea and has drifted in a south-west direction across the North Atlantic (*vide infra*, p. 509). Nordgaard has suggested that areas, such as the North Atlantic, where warm and cold currents meet, and which he terms "boundary areas," are centres of species building and that, if this be so, these areas will also be centres of species distribution; and Lysholm and Nordgaard (1921) have commented on the way in which the currents meet in the North Atlantic and the large number of species of Copepoda that have been described from the North Atlantic Slope. Thanks to the work of several zoologists, among whom may be mentioned Giesbrecht, Sars, Farran, Wolfenden and Rose, we now possess a much better knowledge of the fauna of this area than that of either the Indian or Pacific Oceans. I have been able to collate a list of some 357 species of deep-sea Copepoda that have been taken in this area, and it seems probable that the great majority of these have actually originated in this region.

Calanus finmarchicus (Gunn.).
C. helgolandicus Claus.
C. hyperboreus Kröyer.
C. tenuicornis Dana.
Calanoides brevicornis (Lubb.) (= *Calanus carinatus* Kröyer).
Neocalanus gracilis (Dana).
N. robustior (Giesbr.).
Megacalanus princeps Wolfend.
Bathycalanus bradyi (Wolfend.).
B. princeps Farran (= *rigidus* Sars).
B. richardi Sars.
Bradycalanus sarsi (Farran).
Eucalanus attenuatus (Dana).
E. crassus Giesbr.
E. elongatus (Dana)
E. longiceps Matthews (= *acus* Farran).

Rhincalanus nasutus Giesbr.
Clausocalanus arcuicornis (Dana).
C. pergens Farran.
**Pseudocalanus elongatus* (Boeck).
**Ctenocalanus vanus* Giesbr.
**Spinocalanus abyssalis* Giesbr. and var. *pygmæa* Farran.
S. angusticeps Sars.
S. caudatus Sars.
S. hirtus Sars.
S. horridus Wolfend.
**S. magnus* Wolfend. (= *spinosus* Farran).
S. validus Sars.
Drepanopsis frigidus Wolfend. (= *Farrania oblonga* Sars).
D. pectinatus Brady.
Mimocalanus cultrifer Farran.
M. major Sars.
Isocalanus major Wolfend.
I. minor Wolfend.
Monacilla tenera Sars (= *Hypsicalanus gracilis* Wolfend.).
M. typica Sars (= *dubia* A. Scott, *Oxycalanus spinifer* Farran, *O. semispinus* A. Scott, *O. gracilis* Wolfend.).
Ætideus armatus (Boeck).
Euætideus giesbrechti Cleve (= *Ætideus mediterranea* Steuer).
**Ætideopsis multiserrata* Wolfend. (= *Chiridius nasutus* With).
Æ. rostratus Sars.
Undinopsis bradyi Sars (= *Bradyidius armatus* Giesbr.).
**U. similis* Sars (= *Bradyidius armatus* Vanhöffen).
Bradyetes inermis Farran.
Bryaxis brevicornis Farran.
**Chiridius armatus* (Boeck).
C. gracilis Farran.
**C. obtusifrons* Sars.
C. poppei Giesbr.
Chiridiella macrodactyla Sars.
C. brachydactyla Sars.
Gaidius affinis Sars.
G. brevicaudatus Sars.
**G. brevispinus* Sars (= *major* Wolfend.).
G. minutus Sars.
**G. tenuispinus* (Sars).
G. validus Farran.
Gætanus armiger Giesbr.
G. brachyurus Sars.
G. curvicornis Sars.
G. divergens Wolfend.
G. ferox With.

G. inermis Sars.
G. kruppi Giesbr. (= *major* Wolfend.).
G. latifrons Sars (= *holti* Farran, *longispinus* Wolfend.).
G. miles Giesbr.
G. minor Farran.
G. pileatus Farran.
G. robustus Jespersen.
G. rectus Wolf. (? = *brevicornis* Esterly, *hamatus* A. Scott).
Euchirella amœna Giesbr.
E. bitumida With.
E. brevis Sars.
E. curticauda Giesbr. (= *atlantica* Wolfend.).
E. gracilis Wolfend.
E. intermedia With.
E. maxima Wolfend.
E. messinensis (Claus).
E. pulchra (Lubb.).
E. rostrata (Claus) (= *Euchæta hessei* Brady).
E. spinosa Wolfend.
E. similis Wolfend.
Chirundina abyssalis With.
C. parvispina (Farran).
C. streetsi Giesbr.
Undeuchæta major Giesbr. (= *Chirundina angulata* Sars).
U. plumosa (Lubb.) (= *minor* Giesbr., *Euchæta australis* (Brady)).
Mesundeuchæta asymmetrica Wolfend.
Pseudochirella calcarata Sars.
P. cryptospina Sars (= *Gaidius parvispinus* Farran).
P. divaricata (Sars).
P. dubia Sars.
P. fallax Sars.
P. lobata Sars.
P. notacantha (Sars).
P. obtusa Sars (= *Chirundina abyssalis* With).
P. obesa Sars.
P. palliata Sars.
P. pustulifera (Sars) (= *Euchirella wolfendeni* Farran).
P. scopularis (Sars).
P. superba (With).
Valdiviella brevicornis Sars.
V. insignis Farran.
V. oligarthra Steuer.
Autanepsius major Wolfend.
Pseudeuchæta brevicauda Sars (= *Autanepsius minor* Wolfend.).
Euchæta hebes Giesbr.
E. rubicunda Farran.

E. spinosa Giesbr.
Paraeuchæta barbata (Brady).
P. bisinuata Sars.
P. bradyi With.
**P. glacialis* (Hansen).
P. gracilis Sars (= *quadrata* (Farran)).
P. grandiremis (Giesbr.).
P. hanseni (With).
P. incisa (Sars).
**P. norvegica* (Boeck).
P. sarsi Farran.
P. scotti (Farran).
P. tonsa (Giesbr.).
P. tumidula (Sars).
Phænna spinifera Claus.
Xanthocalanus claviger T. Scott.
X. echinatus Sars.
X. fallax Sars (= *borealis* Sars, 1903).
X. giesbrechti Thompson.
X. greeni Farran (= *calaminus* Wolfend.).
**X. hirtipes* Vanhöffen (= *borealis* Sars, 1900).
X. incertus Sars.
X. mixtus Sars.
X. muticus Sars.
X. obtusus Farran.
X. pinguis Farran.
X. profundus Sars.
X. sub-agilis Wolfend.
X. tenuiremis T. Scott.
X. tenuiserrata Wolfend.
Brachycalanus atlanticus (Wolfend.).
Amallophora typica T. Scott.
A. claviger T. Scott.
Heteramalla dubia Sars.
Onchocalanus affinis With.
O. cristatus (Wolfend.).
O. hirtipes Sars.
O. magnus Wolfend.
O. trigoniceps Sars (= *frigidus* Wolfend.).
Cornucalanus chelifer (Thomp.) (= *magnus* Wolfend.).
C. simplex (Wolfend.).
Undinella oblonga Sars.
U. simplex Wolfend (= *brevipes* Farran).
Cephalophanes refulgens Sars.
Oothrix bidentata Farran.
Scottocalanus helenæ (Lubb.).

S. persecans (Giesbr.) (= *thori* With).
S. securifrons (T. Scott) (= *acutus* Sars).
Lophothrix frontalis Giesbr.
L. humilifrons Sars.
L. insignis Sars.
L. latipes T. Scott (= *Scolecithrix acuta* Wolfend.).
Scaphocalanus affinis Sars (? = *elongatus* A. Scott, ? *Amallophora gracilis* Wolfend.).
S. angulifrons Sars.
**S. brevicornis* (Sars) (= *gracilipes* Farran).
S. curtus Farran.
S. gracilis (Wolfend.).
S. echinatus Farran.
**S. magnus* (T. Scott) (= *acrocephalus* Sars).
S. medius Sars.
S. robustus T. Scott.
Amallothrix arcuata Sars.
A. curticauda (A. Scott).
A. emarginata Farran (= *obtusifrons* Sars).
A. gracilis (Sars) (? = *Scolecithrix globiceps* Farran).
A. laminata (Farran).
A. lobata Sars.
A. obtusifrons (T. Scott, *non* Sars) (= *Amallophora o.* T. Scott, *Scolecithricella tydemani* A. Scott).
A. propinqua Sars.
A. valens (Farran).
A. valida (Farran).
Scolecithrix atlanticus Wolfend.
S. fowleri Farran.
S. scotti Giesbr. (= *Amallophora dubia* T. Scott).
Neoscolecithrix kœhleri Canu (= *Oothrix bidentata* Farran).
Scolecithricella abyssalis (Giesbr.).
S. auropecten (Giesbr.).
S. dentata (Giesbr.).
S. ingolfi With.
S. minor (Brady).
S. ovata (Farran).
S. robusta (T. Scott).
S. tenuiserrata (Giesbr.).
S. vittata (Giesbr.).
Temorites brevis Sars.
Temoropia mayumbœnsis T. Scott.
Centropages typicus Kröyer
Metridia boecki Giesbr.
M. brevicauda Giesbr.
M. curticauda Giesbr.

**M. longa* (Lubb.).
M. lucens Boeck.
M. macrura Sars.
M. princeps Giesbr.
M. venusta Giesbr. (= *normani* Giesbr.).
Gaussia princeps (T. Scott).
Pleuromamma abdominalis (Lubb.).
P. borealis (Dahl).
P. gracilis (Claus).
P. piseki Farran.
P. robusta (Dahl).
P. xiphias (Giesbr.).
Lucicutia atlantica Wolfend. (= *magna* Wolfend., *gracilis* Sars).
L. challengeri Sewell (= *flavicornis* Brady, part).
L. bicornuta Wolfend. (= *aurita* Sars).
L. clausi (Giesbr.).
L. curta Farran.
L. flavicornis (Claus).
L. gemina Farran.
L. grandis (Giesbr.).
L. intermedia Sars.
L. longicornis (Giesbr.).
L. longiserrata (Giesbr.).
L. lucida Farran (= *pera* A. Scott).
L. macrocera Sars.
L. maxima Steuer.
L. ovalis Wolfend.
L. simulans Sars.
L. tenuicauda Sars.
Isochæta longisetosus.
I. ovalis Giesbr. (? = *Lucicutia frigida* Wolfend.).
Disseta palumboi Giesbr. (= *atlantica* Wolfend., *Heterorhabdus grandis* Wolfend.).
**Heterorhabdus abyssalis* (Giesbr.) (= *norvegicus* (Boeck)).
H. brevicornis (Dahl).
H. clausi (Giesbr.).
H. compactus Sars.
H. longicornis (Giesbr.).
H. norvegicus (Boeck) (= *profundus* Dahl).
H. papilliger (Claus).
H. robustus Farran (= *Alloiorhabdus austrinus* Wolfend.).
H. spinifrons (Claus).
H. tropicus Dahl.
H. vipera (Giesbr.).
Hemirhabdus grimaldii (Richard).
H. latus Sars.

Mesorhabdus angustus Sars.
M. brevicaudatus (Wolfend.) (= *annectens* Sars).
M. gracilis Sars.
Heterostylites longicornis (Giesbr.).
H. major (Dahl). (? = *longicornis* (Giesbr.)).
**Haloptilus acutifrons* (Giesbr.) (= *spinifrons* Sars).
H. angusticeps Sars.
H. bulliceps Farran.
H. chierchiæ (Giesbr.).
H. fertilis Giesbr.
H. fons Farran.
H. furcatus Sars.
H. longicornis (Claus).
H. mucronatus (Claus).
H. ornatus (Giesbr.).
H. oxycephalus (Giesbr.).
H. plumosus (Claus).
**H. spiniceps* (Giesbr.).
H. tenuis Farran.
H. validus Sars.
Pseudhaloptilus longimanus Wolfend.
Augaptilus anceps Farran.
A. cornutus Wolfend.
A. glacialis Sars (= *zetesius* Wolfend.).
A. longicaudatus (Claus).
A. megalurus Giesbr.
A. spinifrons Sars.
Euaugaptilus affinis Sars.
E. angustus Sars.
E. bullifer (Giesbr.).
E. clavatus (Sars).
E. digitatus Sars.
E. elongatus Sars.
E. facilis (Farran).
E. farrani Sars.
E. filigerus (Claus).
E. gibbus (Wolfend.).
E. gracilis Sars.
E. grandicornis Sars.
E. hecticus (Giesbr.).
E. humilis Farran.
E. latifrons (Sars).
E. laticeps (Sars) (= *antarcticus* Wolfend.).
E. longicirrhus (Sars).
E. longimanus Sars.
E. magnus (Wolf.) (= *fungiferus* Steuer).

E. maxillaris Sars.
E. nodifrons (Sars).
E. oblongus (Sars).
E. palumboi (Giesbr.).
E. penicillatus Sars.
E. propinquus Sars.
E. rigidus (Sars).
E. similis Farran.
E. squamatus (Giesbr.). (= *brevicaudatus* (Sars)).
E. tenuicaudus (Sars).
E. tenuispinus Sars.
E. truncatus (Sars).
E. vicinus Sars.
Centraugaptilus cucullatus (Sars).
C. horridus (Farran).
C. rattrayi (T. Scott).
Augaptilina scopifera Sars.
Pseudaugaptilina longiremis Sars.
Pontoptilus mucronatus Sars.
P. muticus Sars.
P. ovalis Sars.
P. pertenuis Sars.
P. robustus Sars.
Pachyptilus abbreviatus (Sars).
P. eurygnathus Sars.
P. lobatus Sars.
Heteroptilus acutilobus (Sars).
H. attenuatus (Sars).
Arietellus armatus Wolfend.
A. bispinatus.
A. giesbrechti Sars.
A. pavoninus Sars.
A. plumifer Sars.
A. setosus Giesbr.
A. simplex Sars.
Paraugaptilus buchani Wolfend.
P. meridionalis Wolfend.
Paramisophria cluthæ T. Scott.
Scottula abyssalis Sars.
Phyllopus æqualis Sars.
P. bidentatus Brady.
P. helgæ Farran.
P. impar Farran.
P. muticus Sars.
Bathypontia elegans Sars.
B. elongata Sars.

B. minor Sars.
Candacia armata Boeck.
C. elongata Boeck (= *rotundata* Wolfend., *obtusa* Sars).
C. falcifera Farran (? = *magna* Sewell).
C. longimana Claus.
**C. norvegica* Boeck.
C. tenuimana Giesbr. (= *gracilimana* Farran).
Labidocera wollastoni (Lubb.).
Anomalocera patersoni Templ.
Açartia clausi Giesbr.
Mormonilla phasma Giesbr.
M. minor Giesbr.
Oithona atlantica Farran (= *spinirostris* Sars).
O. setigera Dana (= *pelagica* Farran).
O. similis Claus.
Pontœciella abyssicola (T. Scott).
Paroithona parvula Farran.
Conœa rapax Giesbr.
Ratania atlantica Farran.
R. flava Giesbr.
Lubbockia brevis Farran.
Bathyidia remota Farran.
Microsetella norvegica Boeck.
M. rosea Dana.
Ægisthus aculeatus Giesbr.
Æ. dubius Sars.
Æ. mucronatus Giesbr.

Some of the above species have probably had their origin in the Arctic region and have been able to penetrate southwards into the North Atlantic and beyond; these species I have indicated by an asterisk. A few others appear to have had their origin in the Southern Ocean, and are denizens of the West Wind Drift or of the true Antarctic region and have been carried northwards; such species are *Drepanopsis frigidus* Wolfend., *D. pectinatus* Brady and *Metridia curticauda* Giesbr.

Russell (1935) has pointed out that a consideration of the general trend of the deep currents indicates that cold water species that have evolved from surface-living warm-water species will be carried southwards; he gives figures, supplied by Farran, to show that out of 228 species belonging to 36 deep-sea genera only 3 have succeeded in reaching the Arctic and Boreal region. We have already seen that certain surface-living warm-water species may be swept northwards from the Gulf Stream in the North Atlantic Ocean into the Arctic region, and a few deep-sea species that appear to have had their origin in the North Atlantic seem to have been carried northwards by the North Atlantic Drift; Lysholm and Nordgaard (1921, p. 35) give several such species that have reached as far as the coast of Norway and the Lofoten Islands, or even as far as lat. 70° N., namely:

Eucalanus elongatus (Dana),
Rhincalanus nasutus Giesbr.,
Ætideus armatus (Boeck),

Ætideopsis rostrata Sars,
Paraeuchæta farrani (With),
Haloptilus longicornis (Claus),

and With (1915, p. 166) considers that *Paraeuchæta norvegica* (Boeck) has been carried from the Atlantic to the Arctic Ocean and not *vice versa*; and perhaps *Calanus finmarchicus* (Gunn.) has followed the same route.

But it seems clear that for the majority of those deep-sea species that have been evolved in the North Atlantic Ocean no such northward migration is possible. I have already called attention to the barrier that is presented to such migration by the Wyville-Thompson, the Faroe-Iceland and the Iceland-Greenland Ridges, and between these two last lies Iceland itself. Jespersen (1940, p. 102) has given tables showing the distribution round Iceland of the deep-sea Calanoida that have been captured in that region, and he shows that out of a total of 79 species, 54 are known only from the area to the south of the island and a further 17 only from the south and west areas. Along the north and east sides of the island 8 species have been captured, namely:

**Calanus hyperboreus* Kröyer.
**Spinocalanus abyssalis* Giesbr.
Ætideopsis rostratus Sars.
**Chiridius obtusifrons* Sars.
Euchirella rostrata (Claus).
**Paraeuchæta farrani* (With).
**P. glacialis* (Hansen).
**Scaphocalanus magnus* (T. Scott).

Of the above as many as 6 are in all probability Arctic forms (*vide supra*, p. 495); these I have indicated by an asterisk. Nearly all have been taken also on the south side of the island, the only exception to this being the species *Ætideopsis rostratus* Sars, which, however, is well known from the north Atlantic.

Directly connected with the Atlantic through the Strait of Gibraltar is the Mediterranean Sea, and this forms a separate zoological sub-region, since a number of species that are present in the Atlantic have not, as yet, been taken in the Mediterranean. This enclosed sea is at the present time separated from the North Atlantic below a depth of some 400 m. by the Gibraltar Ridge, and the work of Schott (1928) and others has shown that through this strait there is an inflowing current of surface water, while the deeper water flows out from the Mediterranean Sea into the Atlantic. Thus surface-living plankton can easily be carried from the Atlantic into the Mediterranean, whereas, on the other hand, deep-dwelling forms can be swept out of the Mediterranean Sea into the Atlantic Ocean, but cannot be carried in the reverse direction unless either the adults or, as seems more likely, their larval stages inhabit the upper stratum, or can at least survive in it for a sufficient length of time.

I give below a list of those deep-dwelling Calanoid Copepoda that have been recorded from the deeper water of the Mediterranean Sea:

**Calanus finmarchicus* (Gunn.).
C. helgolandicus (Claus).
**C. tenuicornis* Dana.
**Calanoides brevicornis* (Lubb.).

**Neocalanus gracilis* (Dana).
**Eucalanus attenuatus* (Dana).
**E. elongatus* (Dana).
**Rhincalanus nasutus* Giesbr.
Spinocalanus caudatus Sars.
S. heterocaudatus Rose.
**S. magnus* Wolfend.
Drepanopsis lyra Rose.
Monacilla typica Sars.
**Ætideus armatus* Brady.
**Eucætideus giesbrechti* (Cleve) (= *Ætideus mediterranea* Steuer).
Undinopsis bradyi Sars.
Pseudætideus armatus (Boeck) (= *Chiridius armatus* Sars).
**Chiridius poppei* Giesbr.
**Gætanus kruppi* Giesbr.
**Euchirella messinensis* (Claus).
**E. rostrata* (Claus).
Pseudochirella cryptospina Sars.
**P. obtusa* Sars.
**Euchæta hebes* Giesbr.
**E. spinosa* Giesbr.
**Phænna spinifera* Claus.
Xanthocalanus agilis Giesbr.
X. minor Giesbr.
X. mixtus Sars.
Heteramalla dubia (T. Scott).
Onchocalanus cristatus Wolfend.
O. steueri Pesta.
O. trigoniceps Sars.
**Scaphocalanus magnus* (T. Scott).
Scolecithricella abyssalis (Giesbr.).
**S. dentata* (Giesbr.).
S. longipes (Giesbr.).
S. profunda (Giesbr.).
S. sub-vittata Rose.
**S. tenuiserrata* (Giesbr.).
S. vittata (Giesbr.).
**Amallothrix auropecten* Giesbr.
A. farrani Rose.
A. sarsi Rose.
Metridia lucens Boeck.
**Pleuromamma abdominalis* (Lubb.).
**P. borealis* (Dahl).
**P. gracilis* Claus.
**P. robustus* Dahl.
Lucicutia atlantica Wolfend,

**L. clausi* Giesbr.
L. longiserrata (Giesbr.).
L. lucida Farran.
L. simulans Sars.
**Heterorhabdus papilliger* Claus.
**H. spinifrons* Claus.
**Haloptilus acutifrons* (Giesbr.).
H. angusticeps Sars.
H. fertilis (Giesbr.).
**H. longicornis* (Claus).
**H. mucronatus* (Claus).
**H. ornatus* (Giesbr.).
**H. oxycephalus* Giesbr.
H. plumosus (Claus).
H. spiniceps (Giesbr.).
H. tenuis Farran.
H. validus Sars.
Augaptilus anceps Farran.
**A. longicaudatus* (Claus).
**Euaugaptilus angustus* Sars.
**E. filigerus* (Claus).
**E. hecticus* (Giesbr.).
**E. laticeps* Sars.
**Arietellus setosus* Giesbr.

Of the above 74 species 10, namely—

Spinocalanus heterocaudatus Rose,
Drepanopsis lyra Rose,
Xanthocalanus minor Giesbr.,
X. mixtus Sars,
Onchocalanus steueri Pesta,
Scolecithricella longipes (Giesbr.),
S. sub-vittata Rose,
Amallothrix farrani Rose,
A. sarsi Rose,
Haloptilis fertilis (Giesbr.),

have so far not been recorded from any other area and are possibly endemic ; and Pesta has put forward the suggestion that *Euchæta hebes* Giesbr. originated in the Mediterranean Sea and has been carried thence into the Atlantic Ocean, in which it has been able to spread northwards to the English Channel. Wüst (1936) has concluded from the results obtained by the " Meteor " Expedition in the Atlantic Ocean that the outflowing water from the Mediterranean Sea forms the uppermost stratum of the North Atlantic intermediate water, and that this can be traced right across the North Atlantic in a southwesterly direction and then southwards along the Brazilian coast. Vallaux (1936) doubts whether the Mediterranean outflow is a continuous one, and likens it to " a series of globular masses dispersed both in depth and expanse through the Atlantic, gradually merging with it at various distances, but not by any means extending to the limits of expansion given by Wüst." Iselin (1936) has, however, produced evidence that the effect of this outflow can be traced well into the region of the Sargasso Sea at a depth of 800–1200 m. Whether continuous or intermittent, this outflow must carry with it the fauna of the deeper water of the Mediterranean Sea, and thus can well account for the presence of Mediterranean species in the Atlantic Ocean, whence, as we shall see later, they can be dispersed to both Indian and Pacific Oceans.

The fact that no less than 40 species out of a total of 74, or 54 per cent., as indicated in the above list by asterisks, are known to be present in all three great oceans, Atlantic, Indian and Pacific, while 14 others, namely—

Calanus helgolandicus (Claus),
Spinocalanus caudatus Sars,
Monacilla typica Sars,
Xanthocalanus agilis Giesbr.,
Heteramalla dubia (T. Scott),
Onchocalanus cristatus Wolfend.,
Scolecithricella dentata (Giesbr.),
S. vittata (Giesbr.),
Lucicutia atlantica Wolfend.,
L. longiserrata (Giesbr.),
L. lucida Farran,
Haloptilus angusticeps Sars,
H. plumosus Claus,
H. spiniceps (Giesbr.),

are known from the Atlantic and Pacific Oceans, though they have not, as yet, been recorded from the Indian Ocean, might well be regarded as evidence in favour of the view that the Mediterranean Sea, being the last remaining portion of the older Tethys Sea, has in times past acted as a highway along which Indo-Pacific forms could be carried westward into the Atlantic Ocean, and that their presence to-day in this Mediterranean sub-region is due to their survival since early Tertiary times. I have, however, previously (*vide supra*, p. 473) pointed out that it has been suggested that during the Pleistocene Glacial epoch the Mediterranean Sea became completely cut off from the Atlantic, and during this period was reduced to two isolated inland lakes, such as the Caspian and Dead Seas are to-day ; such a change must have resulted in the extermination of its original marine fauna, and the present population must have been introduced subsequently to the melting of the ice and have come from the Atlantic Ocean. The supposition that the Mediterranean fauna originated, at any rate in part, from the Indo-Pacific region presupposes that these species originated in the Indo-Pacific area and spread westward, but I have already mentioned that the great majority of species that are to-day found in the deeper levels of the Atlantic Ocean appear to have had their origin in that region and, as we shall see later, the distribution of these species throughout the other great oceans indicates that migration has been from west to east, and not *vice versa*. The fact that, with the exception of the ten "endemic" species, all the others are known to occur in the Atlantic Ocean, is best accounted for on the supposition that they are truly Atlantic species and have been swept eastward into the Mediterranean Sea on the one hand, and southward and then eastward into the Indian and Pacific Oceans on the other. If they have been carried into the Mediterranean Sea from the Atlantic they must have been living during some stage or other of their existence in the upper levels above 400 m. depth, and the fact that they have been able to survive in water that is known to have a uniform temperature of about 12·5° C., that being the temperature at all depths in the Mediterranean Sea below the level of the Strait of Gibraltar, would seem to indicate that they do possess this faculty. It is also well known that from time to time examples of deep-sea species are taken at or near the surface, and a study of the available records has shown that as many as 46 contained in the above list have been recorded from the upper levels of the Atlantic Ocean at less than 400 m. depth; and Rose (1925) has recorded 17 in the Mediterranean Sea in less than 210 m. depth. It would seem clear, therefore, that there is nothing inherently impossible or even improbable in the suggestion that the great majority of the deep-dwelling species in the Mediterranean Sea have been carried in from the Atlantic Ocean, and that this process may be going on at the present time.

As I have already mentioned (*vide supra*, p. 498), Wüst (1928, p. 522) has pointed out that the North Atlantic Intermediate Current is composed of water from three different sources. These distinct water masses must all contribute their share of plankton to the main stream. The main mass of the North Atlantic Intermediate water (*vide* Wüst, 1935, 1936) crosses the Equator on the west side of the ocean and passes southwards close to the Brazilian coast. In the southern hemisphere the current develops an easterly trend and tends to spread out; some of the water enters the Gulf of Guinea, though this movement appears to be more of the nature of a diffusion or of slow vortices than an actual current. Further south, between lats. 20°–30° S. a branch of this current flows across the whole width of the South Atlantic and past the Cape of Good Hope into the southern part of the Indian Ocean, where it has been detected at a depth of about 3000 m. (*vide* Clowes and Deacon, 1935). Finally, the remaining mass of the North Atlantic Intermediate water tends to rise towards the surface throughout the greater part of the Antarctic region that lies between the Weddell Sea eastwards as far as the longitude of the Cape of Good Hope. As Deacon (1937) has pointed out, there are certain localities in the Antarctic from which this deep warm water of the North Atlantic Intermediate Current is partly or wholly excluded by submarine ridges, as, for instance—

1. Vahsel Bay, south of the Weddell Sea.
2. Part of Ross Sea.
3. Bransfield Strait.

Probably there are many small basins, which possess similar conditions, near the Antarctic continent, and some even further north, such as Douglas Strait in the S. Sandwich Group and Moränen and Drygalski fjords in S. Georgia.

Brennecke (1921) supposed that the warm intermediate layer in the region of the Weddell Sea was formed by an outflow of water from the Indian Ocean towards the west, and this view was accepted by Drygalski (1926), who suggested that it was a part of the Agulhas Current, which presumably sank down and flowed westward to the Weddell Sea beneath the Sub-Antarctic Intermediate layer. Lohmann (1928) adopted this view and used it to explain the presence of warm-water planktonic forms in the Weddell Sea region, and he was followed by Steuer (1933, p. 295), who pointed out that the plankton of the high seas can penetrate for considerable distances into the deeper layers and so can be carried about by the deep currents, so that cold-water forms are sometimes taken in the tropics and tropical forms occasionally make their appearance in the Antarctic. It is unfortunate that both these last authors based their explanation on the supposed existence of a deep current setting south-westward from the Indian Ocean, for it now seems reasonably certain that the intermediate water in the Weddell Sea area and considerably to the east of it is derived from the North Atlantic Intermediate Current.

Wolfenden (1908, p. 3) pointed out that a number of species have been taken in Antarctic and Sub-Antarctic waters that " belong undoubtedly to a sub-tropical or warm temperate area and are to be regarded as accidental " in this southerly region. Among such species he enumerates the following :

Surface-living Species.

Eucalanus subtenuis Giesbr.
Euchæta marina (Prestand.).
Centropages violaceus (Claus).
Lucicutia flavicornis (Claus).
Candacia sp.
Labidocera acutifrons (Dana).

Deep-dwelling Species.

Ætideus armatus Brady.
Undeuchæta major Giesbr.
Pleuromamma gracilis (Claus).
Arietellus setosus Giesbr.

The occurrence of such species on several occasions and in several different localities in the Antarctic region can, I think, hardly be regarded as " accidental." The general trend of the surface and deep currents, and the fact that where such currents impinge on one another there is a certain, and possibly a considerable, degree of admixture of the water, provides a perfectly rational explanation of the presence in southern latitudes of such warm-water surface species as are sufficiently hardy to withstand the change of temperature encountered in passing from one current to another, while deep-dwelling species can be transferred from one water mass to another, experiencing only a very small change in the temperature, salinity or oxygen-content of the water. Russell (1935, pp. 10–12) has called attention to the manner in which the deep currents of the Atlantic Ocean, and especially the movement of the North Atlantic Intermediate Current, must tend to carry species from the Arctic and North Temperate regions southwards into Sub-Antarctic and Antarctic waters, and he gives a list of species that, as a result of this, are found to be " bipolar epiplanktonic " in their distribution, namely :

Microcalanus pygmæus Sars.
Scaphocalanus magnus (T. Scott).
Metridia lucens Boeck.
M. longa (Lubb.).
Heterorhabdus compactus Sars.
Candacia falcifera Farran (? = *magna* Sewell).

Thanks to the work of Giesbrecht (1902), Wolfenden (1911), Farran (1929), Mackintosh (1934), Hardy and Gunther (1935) and Wilson (1938) we now have records of no less than 96 Arctic or North Atlantic species that have been taken in Antarctic and Sub-Antarctic waters:

Calanus carinatus Kröyer (= *C. brevicornis* Lubb.).
**C. finmarchicus* (Gunn.).
**C. tenuicornis* Dana.
C. tonsus Brady.
**Neocalanus gracilis* (Dana).
**Calanoides brevicornis* (Lubb.).
Nannocalanus minor (Claus).
**Megacalanus princeps* Wolfend.
**Bathycalanus bradyi* (Wolfend.).
? **Eucalanus longiceps* Matthews (= *acus* Farran).†
**E. elongatus* (Dana).
**Rhincalanus nasutus* Giesbr.
Clausocalanus arcuicornis (Dana).
C. furcatus (Brady).
C. laticeps Farran.
Ctenocalanus vanus Giesbr.
Microcalanus pygmæus Sars.
Spinocalanus abyssalis Giesbr., represented by var. *pygmæus*.
S. horridus Wolfend. (? = *S. spinosus* Farran).‡
**S. magnus* (Wolfend.).
S. spinosus Farran.
**Eucætideus giesbrechti* (Cleve).
**Ætideus armatus* Brady.
**Bradyidius armatus* Vanhöffen.
**Gaidius tenuispinus* (Sars).
**Pseudochirella notacantha* (Sars).
P. pustulifera (Sars) (= *Chirundina p ustulifera* Sars).
**Undeuchæta major* Giesbr.
**U. plumosa* (Lubb.) (= *minor* Giesbr.).
**Euchirella rostrata* (Claus).
Xanthocalanus tenuiserratus Wolfend.
Paraeuchæta farrani (With).
**P. scotti* (Farran).
**Onchocalanus magnus* Wolfend.
**O. trigoniceps* Sars (= *frigidus* Wolfend.).
O. cristatus Wolfend.
**Cornucalanus chelifer* (Thompson) (= *magnus* Wolfend.).
Scolecithrix römeri Mrazek.§

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† In a previous paper (Sewell, 1929, p. 50) I have pointed out that I believe *Eucalanus acus* Farran to be a synonym of *E. longiceps* Matthews, and that the species recorded by With (1915, p. 52) from the North Atlantic under the title ? *Eucalanus attenuatus* (Dana) is the same form.

‡ *Spinocalanus horridus* Wolfend. is at present known only from the tropical Atlantic to the west of Cape Verde Islands; *S. spinosus* Farran has been recorded from the west of Ireland and the Antarctic.

§ This species is according to Brady (1918, p. 23) synonymous with *Scolecithrix glacialis* Giesrb. from the Antarctic.

Scolecithricella minor (Brady).
S. ovata Farran.
S. robusta T. Scott.
**Amallothrix emarginata* Farran (= *obtusifrons* Sars).
**A. valida* Farran.
**Scaphocalanus affinis* Sars.
S. brevicornis (Sars).
S. echinatus (Farran).
**S. magnus* (T. Scott).
Temora turbinata (Dana).
**Metridia boecki* Giesbr.
**M. brevicauda* Giesbr.
**M. longa* (Lubb.).
**M. lucens* Boeck.
**M. princeps* Giesbr.
**Pleuromamma abdominalis* (Lubb.).
**P. borealis* (F. Dahl).
**P. gracilis* (Claus).
**P. robustus* (F. Dahl).
**P. xiphias* (Giesbr.).
Lucicutia atlantica (Wolfend.) (= *L. magna* Wolfend.).
**L. bicornuta* Wolfend. (= *L. aurita* Sars).
L. grandis (Giesbr.).
**Disseta palumboi* Giesbr.
Heterorhabdus robustus Farran (= *Alloiorhabdus austrinus* Wolfend.).
H. compactus Sars.
**Heterostylites longicornis* (Giesbr.).
**H. major* (F. Dahl).†
Haloptilus fons Farran.
**H. longicornis* (Claus).
**H. oxycephalus* (Giesbr.).
H. spiniceps (Giesbr.).
**Euaugaptilus laticeps* Sars.
**Augaptilus megalurus* Giesbr.
**Centraugaptilus rattrayi* T. Scott.
**Arietellus setosus* Giesbr.
**Phyllopus bidentatus* Brady.
P. helgæ Farran.
**Candacia falcifera* Farran (? = *magna* Sewell).
Acartia clausi Giesbr.
A. danæ Giesbr.
Mormonilla phasma Giesbr.
M. minor Giesbr.
Oithona plumifera Baird.

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† As I have previously pointed out (Sewell, 1932, p. 303), I am of the opinion that *Heterostylites longicornis* and *H. major* are merely size groups of the same species.

O. similis Claus.
Oncæa conifera Giesbr.
O. mediterranea Giesbr.
O. notopus Giesbr.
Conæa rapax Giesbr.
Ratania atlantica Farran.
Corycæus (Corycæus) speciosus Dana.
C. (Agetes) flaccus Giesbr.
C. (Urocorycæus) furcifer Claus.
Sapphirina metallina Dana.
Ectinosoma melaniceps Boeck.
Microsetella norvegica (Boeck).
Macrosetella gracilis (Dana).
Clytemnestra rostrata Brady.

A number of these species are surface-living forms, and these may have reached the Sub-Antarctic and Antarctic regions by passing across the convergence zones (*vide supra*, p. 453 *et seq.*). The great majority, however, are deep-dwelling forms, and in all probability have been swept southwards in the North Atlantic Intermediate or bottom currents. In its deepest levels the Atlantic Ocean is known to be divided into two series of basins, eastern and western, that are separated from each other by the Mid-Atlantic Ridge, and Wüst (1938) has published a very interesting chart in which he shows the origin and distribution of the deep water in these two series of basins; he shows that the eastern series is filled with water that has its origin in the Arctic Ocean, whereas in the western series the water is in the main derived from the Antarctic, only a relatively small area in the western part of the North Atlantic being supplied with water from the Arctic region. The southward flow of Arctic bottom water along the eastern series of basins is finally stopped in the South Atlantic by the Walfisch Ridge, that connects the Mid-Atlantic Ridge with the African continent, but Wüst (1928) has shown that the last part of the southward flow of the North Atlantic Bottom Drift can be traced in the South Atlantic past the Rio Grande and Walfisch Ridges, and that it then turns sharply towards the surface, reaching a depth of some 800 m. in about lat. 56° S.

The same author has put forward the view that in the area of the Antarctic region lying between lats. 65°–69° S. and longs. 27°–45° W. there is a vertical "change over" of water, the surface water sinking down in the winter months and being replaced by up-welling water that is ultimately derived from the Atlantic Intermediate Current. Such an up-welling will carry with it examples of species that normally inhabit the warmer Atlantic current, and will bring them into cold Antarctic water that is carried northwards to reach the Sub-Antarctic convergence zone, where it sinks down and forms part of the Sub-Antarctic Intermediate Current. We thus should not be surprised to find that as many as 68 or 69 deep-sea species are common to the North Atlantic Ocean and the Sub-Antarctic region; and of these (48) indicated in the above list by an asterisk, are known from the Indian Ocean.

If these deep-sea species have been swept from the North Atlantic region to the Antarctic by the North Atlantic Intermediate Current, the main mass of which passes down the west side of the South Atlantic Ocean along the Brazilian coast, and only a small offset or even merely a series of vortices carries this water across to the African side, we might still expect to find that some at least of these North Atlantic species were to be found in the Gulf of Guinea and the region to the south of it. T. Scott (1894) and others have recorded the following species from this area :

Calanus propinquus Brady.
C. tonsus Brady.
Neocalanus gracilis (Dana).
N. robustior (Giesbr.) [as ? *Calanus comptus* Dana].
Rhincalanus nasutus Giesbr.
Eucalanus attenuatus (Dana).
E. elongatus (Dana) [as *E. spinifer* T. Scott].
Ætideus armatus Brady.
Gætanus armiger Giesbr.
Gaidius similis (T. Scott) [as *Euchæta hessei* var. *similis*].
G. tenuispinus (Sars).
Euchirella pulchra Lubb.
E. messinensis (Claus).
Undeuchæta major Giesbr.
Valdiviella oligarthra Steuer.
Paraeuchæta valida (T. Scott) [as *Euchæta hebes* var. *valida* T. Scott].
Amallophora typica T. Scott.
Heteramalla dubia (T. Scott).
Phænna spinifera Claus.
Scolecithricella abyssalis Giesbr. [as *S. tumida* T. Scott].
S. ctenopus Giesbr.
S. dubia Giesbr.
S. longicornis T. Scott.
S. robusta T. Scott.
S. scotti Giesbr. [as *Amallophora dubia* T Scott].
S. similis T. Scott.
S. tenuipes T. Scott.
Lophothrix latipes (T. Scott).
Scaphocalanus magnus (T. Scott).
S. major (T. Scott).
Scottocalanus securifrons (T. Scott).
Pleuromamma abdominalis (Lubb).
P. gracilis (Claus).
Gaussia princeps (T. Scott).
Heterorhabdus spinifrons (Claus).
Euaugaptilus hecticus (Giesbr.).
Augaptilus longicaudatus (Claus).
Centraugaptilus rattrayi (T. Scott).
Haloptilus longicornis Claus.
H. mucronatus (Claus).
H. plumosus Claus.

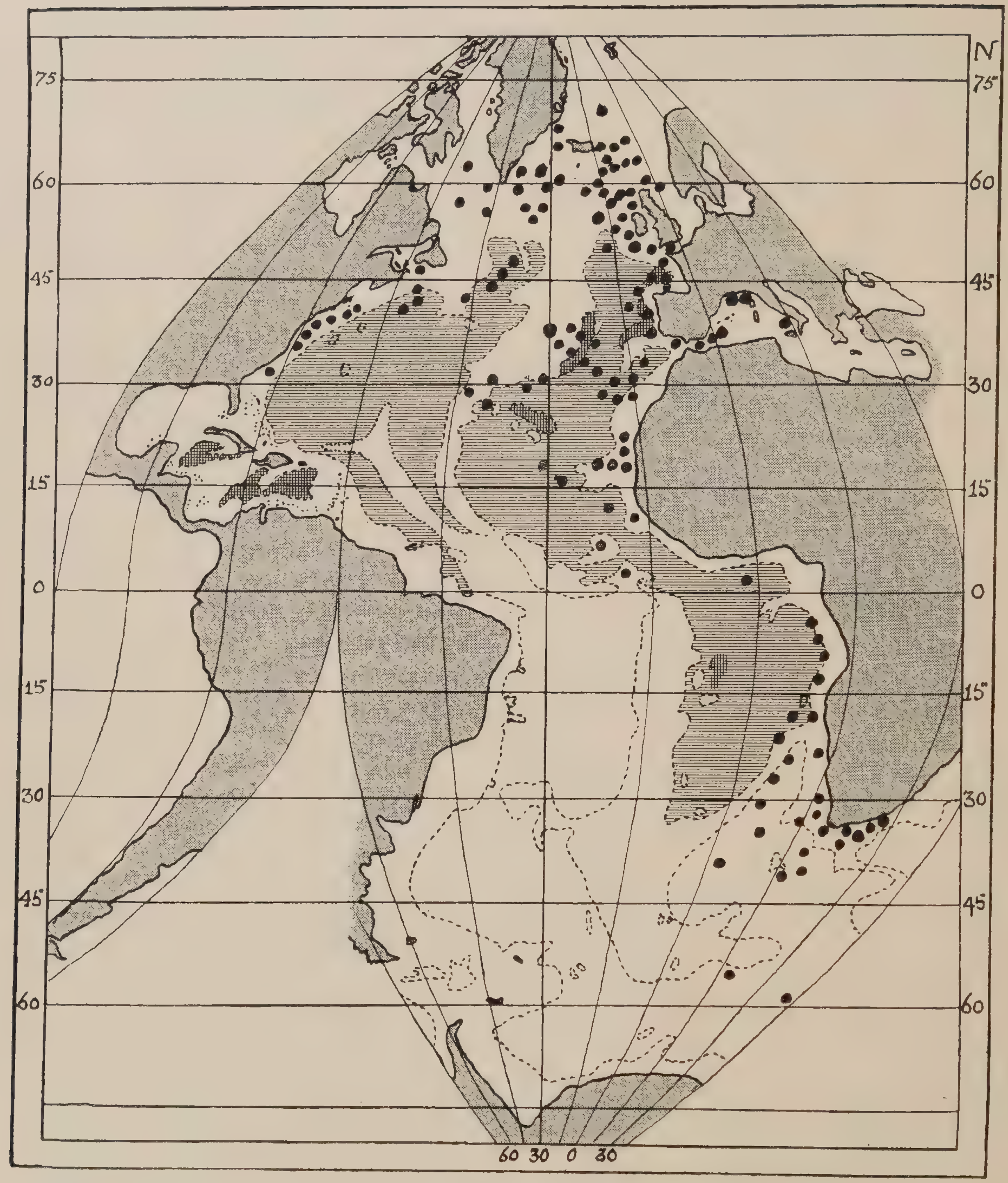
Arietellus setosus Giesbr. [as *Rhincalanus aculeatus* T. Scott].
Phyllopus bidentatus Brady.
Mormonilla phasma Giesbr.

An analysis of the above list reveals that out of the total of 44 species, three are known to be Arctic forms, namely, *Calanus tonsus* Brady, *Gaidius tenuispinus* (Sars) and *Scaphocalanus magnus* (T. Scott); one species, *Calanus propinquus* Brady, is usually regarded as an Antarctic form and five appear to be endemic, namely:

Paraeuchæta valida (T. Scott).
Scolecithricella scotti Giesbr.
S. similis (T. Scott).
S. robusta (T. Scott).
S. tenuipes (T. Scott).

All the others are known from other regions. In this connection it is interesting to note that certain species, that are usually taken in the North Atlantic in depths that correspond to the North Atlantic Intermediate Current, appear to have a distribution that much more closely approximates to the flow of the bottom water. This is especially clear in the case of *Rhincalanus nasutus* (Dana). In Text-fig. 89 I have given the general distribution of this Arctic bottom water, taken from Wüst (1938), and have superposed on it the distribution in the Atlantic of this species, taken, with a few additions, from the corresponding charts of Schmaus and Lehnhofer (1927) and Steuer (1931*b*); from this it appears that the actual distribution of this species agrees exactly with what one would expect were it due to the movement of the Arctic bottom water.

Wüst (1935, p. 141) states that the branch of the North Atlantic Intermediate Current that sets eastward in about lat. 40°–45° S., after passing to the south of the Cape of Good Hope and entering the Indian Ocean, is partly reflected by the Kerguelen-Gaussberg Ridge and then turns back and flows westward in the southern half of the Atlantic-Indian South Polar Basin as an undercurrent, which eventually reaches the Weddell Sea; Sverdrup (1931), Schott (1933), Clowes and Deacon (1935) and Deacon (1937) are all of the opinion that a mass of Atlantic water, derived from the North Atlantic Intermediate Current, swings eastward past the Cape of Good Hope, and can be traced right across the southern part of the Indian Ocean and on into the south-west region of the Pacific. In the south-west region of the Indian Ocean, lying above this branch of the North Atlantic Intermediate Current, is a mass of water that is flowing northwards into the Indian Ocean, the Antarctic Intermediate Current. We should thus expect to find that either vertical migration from one water mass to the other, or actual admixture of these two masses of water along the boundary line between them, will transfer some at least of the North Atlantic species from the branch of the North Atlantic Intermediate Current to the Antarctic Intermediate Current, and that in consequence we shall find them in the tropical and sub-tropical regions of the Indian Ocean and the south-west Pacific Ocean, though, if Störmer (1933) be correct in his view that as we pass along a given current of water the number of species present at the outset steadily decreases, the actual numbers of North Atlantic species present should be greater in the Indian Ocean than in the Pacific region. Steuer (1933, p. 296) has already pointed out that the extension of the habitat of *Pleuromamma xiphias* (Giesbr.) into the equatorial region of the Indian Ocean in about 700 m. depth is due to the Antarctic Intermediate Current.



Text-fig. 89.—Showing the distribution of *Rhincalanus nasutus* Giesbr. and the flow of Arctic bottom water in the Atlantic Ocean. (After Wüst.)

Up to the present time comparatively little work has been carried out on the deep-dwelling Copepoda of the region round the Cape of Good Hope. Cleve (1904) and Stebbing (1910) have given the following species as inhabitants of this region; they were collected off the south-east coast of South Africa at depths ranging from 530–900 m.:

**Calanus finmarchicus* (Gunn.).
**C. tenuicornis* Dana.
Eucalanus attenuatus (Dana).
**E. elongatus* (Dana).
**Rhincalanus nasutus* Giesbr.
**Euætideus giesbrechti* (Cleve).
Gætanus armiger Giesbr.
G. miles Giesbr.
Chiridius poppei Giesbr.
Chirundina streetsi Giesbr.
**Undeuchæta major* Giesbr.
U. minor Giesbr. (= *plumosa* (Lubb.)).
Euchirella messinensis (Claus).
E. venusta Giesbr.
Paraeuchæta tonsa Giesbr.
P. affinis Cleve.
Scottocalanus persecans (Giesbr.).
S. securifrons (T. Scott).
Phænna spinifera Claus.
**Metridia brevicauda* Giesbr.
**M. princeps* Giesbr.
M. venusta Giesbr.
**Pleuromamma abdominalis* (Lubb.).
**P. gracilis* (Claus).
**P. robusta* (F. Dahl).
**P. xiphias* (Giesbr.).
Lucicutia aurita Cleve (non *L. aurita* Sars).
L. bradyana Cleve.
L. clausi Giesbr.
Heterorhabdus abyssalis Giesbr.
H. austrinus Giesbr.
H. papilliger (Claus).
H. spinifrons (Claus).
H. tanneri Giesbr.
Euaugaptilus palumboi Giesbr.
**Phyllopus bidentatus* Brady.

Cleve refers to these species as inhabitants of the Agulhas Current, but the depth from which they were taken seems to indicate that they were not inhabitants of this current but of the water layer lying immediately below it, namely, the Sub-Antarctic Intermediate Current. Out of a total of 36 species four have not been recorded from any area to the west of the Cape of Good Hope, namely, *Euchirella venusta* Giesbr., *Paraeuchæta affinis*

Cleve, *Lucicutia aurita* Cleve and *L. bradyana* Cleve ; one species, *Heterorhabdus austrinus* Giesbr., appears to be an Antarctic species that has been swept northwards, and *H. tanneri* Giesbr. is a Pacific form ; all the remaining 30 species are known from the North Atlantic Ocean, and of these 13 are among the North Atlantic forms that have been recorded from the Antarctic region ; these I have indicated by an asterisk in the above list. A further 14 species from the Cape region are common to both the Atlantic and Indian Oceans, but seem to have made their way from the one to the other by some route that does not entail penetration of the Sub-Antarctic region ; and this is almost certainly the Indo-Pacific branch of the North Atlantic Intermediate Current. In addition to the species of North Atlantic Copepoda that have been carried southwards into the Antarctic region, a number that are not sufficiently hardy to survive transference to the Sub-Antarctic area appear to have been swept eastward by the branch of the North Atlantic Intermediate Current into the south-western region of the Indian Ocean and then have been carried northwards, presumably in the Sub-Antarctic Intermediate water, so that they have been captured in the Arabian Sea or the Bay of Bengal to the west or east of India respectively. These species are as follows :

Calanoides patagoniensis Brady,
Neocalanus robustior (Giesbr.),
Bathycalanus richardi Sars,
Eucalanus attenuatus (Dana),
Monacilla tenera Sars,
Undinopsis bradyi Sars,
Chiridius gracilis Farran,
Gaidius minutus Sars,
Gætanus armiger Giesbr.,
G. curvicornis Sars,
G. kruppi Giesbr.,
G. latifrons Sars,
G. miles Giesbr.,
G. minor Farran,
G. pileatus Farran,
G. rectus Wolfend.,
Euchirella brevis Sars,
E. curticauda Giesbr.,
E. galeata Giesbr. (= *bitumida* With),
E. maxima Wolfend.,
E. messinensis (Claus),
E. pulchra (Lubb.),
E. truncata Esterly,
Chirundina streetsi Giesbr.,
Undeuchæta plumosa (Lubb.) (= *minor* Giesbr.),
Pseudeuchæta brevicauda Sars,
Pseudochirella cryptospina Sars,
P. notacantha Sars,
P. obtusa Sars,

Valdiviella brevicornis Sars,
V. insignis Farran,
V. minor Wolfend.,
V. oligarthra Steuer,
Euchæta spinosa Giesbr.,
? *Paraeuchæta barbata* (Brady),
P. bisinuata (Sars),
P. hanseni (With),
P. sarsi (Farran),
P. scotti (Farran),
P. tonsa (Giesbr.),
P. withi sp. nov.,
Phænna spinifera Claus,
Xanthocalanus greeni Farran,
Onchocalanus affinis With,
O. trigoniceps Sars,
Cornucalanus simplex Wolfend.,
C. chelifer (Thompson),
Scottocalanus helenæ (Lubb.),
S. persecans (Giesbr.),
S. securifrons (T. Scott),
Lophothrix frontalis Giesbr.,
L. humilifrons Sars,
L. quadrispinosa Wolfend.,
Scaphocalanus affinis Sars,
S. magnus (T. Scott),
S. medius Sars,
Scolecithricella tenuiserrata (Giesbr.),
Amallothrix arcuata Sars,
A. emarginata (Farran) (= *obtusifrons* Sars),
A. gracilis Sars,
Metridia curticauda Giesbr.,
M. macrura Sars,
M. princeps Giesbr.,
Pleuromamma indica Wolfend.,
P. quadrungulata (Dahl),
Gaussia princeps (T. Scott),
Lucicutia challengeri Sewell,
L. clausi Giesbr.,
L. maxima Steuer,
L. ovalis Wolfend.,
L. magna Wolfend.,
Heterorhabdus abyssalis (Giesbr.),
H. clausi (Giesbr.),
H. papilliger (Claus),
H. spinifrons (Claus),

H. vipera (Giesbr.),
Hemirhabdus grimaldii (Richard),
? *H. truncatus* (A. Scott) (? = *latus* Sars),
Euaugaptilus angustus Sars,
E. bullifer (Giesbr.),
E. digitatus Sars,
E. elongatus Sars,
E. facilis (Farran),
E. filigerus (Claus),
E. hecticus (Giesbr.),
E. grandicornis Sars,
E. latifrons Sars,
? *E. longicirrhus* Sars,
E. longimanus Sars,
E. magnus (Wolfend.),
E. nodifrons Sars,
E. oblongus Sars,
E. penicillatus Sars,
E. tenuispinus Sars,
Augaptilus longicaudatus (Claus),
Centraugaptilus horridus (Farran),
Haloptilus acutifrons (Giesbr.),
H. chierchiæ (Giesbr.),
H. mucronatus (Claus),
H. ornatus (Giesbr.),
H. oxycephalus (Giesbr.),
H. validus Sars,
Heteroptilus acutilobus Sars,
Pontoptilus ovalis Sars,
Arietellus giesbrechti Sars,
A. plumifer Sars,
A. simplex Sars,
Pachyptilus eurygnathus Sars,
P. lobatus Sars,
Phyllopus impar Farran,
P. muticus Sars,

and to these, in all probability, should be added the following Atlantic species that normally inhabit the upper stratum, but which appear to have been swept eastward occasionally from the Atlantic Ocean into the Indian Ocean by the branch of the North Atlantic Intermediate Current :

Calanus finmarchicus (Gunn.).
Ctenocalanus vanus Giesbr.
Euchæta hebes Giesbr.
Anomalocera patersoni Templ.
Labidocera nerii (Kröyer).

Pontella atlantica (M.E.).
P. mediterranea (Claus).
Parapontella brevicornis (Lubb.).
Centropages chierchiæ Giesbr.
C. typicus Kröyer.

A certain number of other species, which in spite of the extended researches that have been carried out in that area have not up to the present time been recorded from the North Atlantic Ocean, have been described by Wolfenden (1911) from the deeper levels of the ocean beneath the equator or in the South Atlantic Ocean. These species are as follows :

Mesogaidius maximus (? = *Gaidius validus* Farran),*
Gœtanus brevicaudatus,
G. recticornis,
Pseudochirella magna (= *Chirundina magna*),
P. spinosa,
Chiridiella atlantica,
Mesundeuchæta asymmetrica,
Valdiviella minor,
Euchæta exigua (= *Paraeuchæta exigua*),
Onchocalanus subcristatus,
Scolecithrix æqualis,
S. magnus,
S. medius,
Amallophora elegans,
Lophothrix quadrispinosa,
L. similis,
L. simplex,
L. varicans,
Lucicutia major,
Hemirhabdus falciformis,
Euaugaptilus simplex (? = *E. nodifrons* Sars),*
E. subfiligerus,
Haloptilus major,
Arietellus minor,

and to this list we may add the following species :

Paraeuchæta valida (? = *P. barbata* (Brady)),*
Scolecithrix tumida (? = *S. abyssalis* Giesbr.),*
S. longicornis,
S. major (? = *Scaphocalanus medius* Sars),*
S. scotti Giesbr. (= *Amallophora dubia* T. Scott),
S. similis (= *Amallophora dubia* var. *similis*),
S. robusta (= *Amallophora robusta*),
Scolecithricella ctenopus (Giesbr.),
S. tenuipes,
Arietellus aculeatus (= *Rhincalanus aculeatus* T. Scott),

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* If, as I believe, these species are synonymous, they are North Atlantic species, and their names should be added to the list on pp. 498–506.

which were recorded by T. Scott (1894) from the Gulf of Guinea. The majority of the above species were taken in the eastern part of the Atlantic Ocean from the equator southwards in hauls ranging from 1000 to 3000 m. depth, and reference to the charts of salinity in this section of the ocean given by Wüst (1935, Chart 27) shows that at these depths the species must have been inhabiting the North Atlantic Intermediate water; but, as Wüst has shown, the main stream of this current runs down the west side of the Atlantic, off the coast of Brazil, and although some of this water finds its way across the South Atlantic to the west coast of Africa, this is brought about more by diffusion and vortices than as part of a direct stream. Furthermore, it is now well established that off the west and south-west coast of South Africa a mass of deep water wells up towards the surface, where it mixes with a branch of the West Wind Drift and with an offshoot from the Agulhas Current to form the Benguela Current, that runs first towards the north-west and then west across the Atlantic. Thus there seems to be little or no opportunity for species in this eastern part of the South Atlantic to get carried eastward into the Indian Ocean, and it is thus not surprising that out of the above 34 species, if we exclude those that are doubtful inhabitants of the North Atlantic, only 5 have been taken in the Indian Ocean or its offshoot, the Red Sea, namely:

Pseudochirella magna (Wolfend.),
Valdiviella minor Wolfend.,
Lophothrix quadrispinosa Wolfend.,
Scolecithricella ctenopus (Giesbr.),
S. tenuipes (T. Scott),

and only two are known from the Pacific Ocean—

Scolecithricella ctenopus (Giesbr.),
S. longicornis (T. Scott).

We thus have a grand total of some 165 species of deep-water Copepoda that have been recorded from both the Atlantic and the Indian Oceans, and whose presence in this latter area can be accounted for by transportation, first, along the branches of the North Atlantic Intermediate Current that flow either to the Sub-Antarctic region or past the Cape of Good Hope into the southern part of the Indian Ocean and on to the south-west area of the Pacific Ocean, and secondly, by the Sub-Antarctic Intermediate Current northwards to the Arabian Sea and the Bay of Bengal. In the case of the great majority of these species, they have been taken in the Indian Ocean in depths that seem to correspond to this water mass, but for a few species, such as *Paraeuchæta hanseni* With, *Valdiviella insignis* Farran and *Bathycalanus bradyi* Wolfend., which were taken in the Arabian Sea at depths of 2000 m. or over, it is probably the Antarctic Bottom Drift that is responsible for their northward transference.

The Indian Ocean, like the Atlantic, is divided into eastern and western regions by the Kerguelen-Gaussberg Ridge and its continuation northwards in the Carlsberg and Murray Ridges, the whole series forming the Mid-Indian Ridge; both regions are composed of a series of basins (*vide* Wiseman and Sewell, 1937, and Sewell, 1937). Möller (1929) put forward the view that the Sub-Polar water sinks down in lats. 40°–60° S., and then flows northwards in the Indian Ocean at a depth of from 500 to 2000 m. to about lat, 20° S., after which it gradually thins out as it reaches the equator and finally disappears in about lat. 5° N.; but from the work of the "John Murray" expedition Mohamed (1940) has been able to show that this Sub-Polar water, which he terms the Antarctic Intermediate Current, can be clearly traced northwards into both the Gulf of Aden and the Gulf of Oman. We should expect to find that the effect of the Mid-Indian Ridge, combined with the effect of the earth's rotation, will tend to deflect the greater part of the Antarctic Intermediate water against the African coast; Mohamed (1940, p. 192), from his study of the pH distribution, reached the conclusion that "the Antarctic Intermediate Current enters the area of the north-western Indian Ocean mainly on the western side. It then tends to move north-eastward," and in the Arabian Sea it is divided into an upper and a lower stratum by the Indian Intermediate Current that is flowing southwards. The upper stratum divides into easterly and westerly branches, the latter moving towards the Gulf of Aden; the deeper stratum spreads widely at a depth of 2000 m. and reaches as far north as the Gulf of Oman. The Arabian basin is filled at a depth of 2000 m. with this Antarctic water. Steuer (1933) quotes Defant as saying that the Antarctic Intermediate Current does not penetrate into the Bay of Bengal, and to the absence of this water he attributes the absence in this area of the large cool-water form of *Pleuromamma xiphias* Giesbr. We have already seen that a number of North Atlantic species are carried southwards into the Antarctic and Sub-Antarctic region of the Atlantic Ocean, and if these be, as I have suggested, carried northwards again into the Indian Ocean in the Antarctic Intermediate Current, we should expect to find that their distribution in the Indian Ocean shows an agreement with the distribution of this cool water. Of the 96 North Atlantic species taken in the Antarctic, a full list of which is given above on p. 513, 46 have been taken in the Indian Ocean; of these, 19 species are common to both east and west regions of the Indian Ocean and have been taken on both sides of the Mid-Indian Ridge, namely:

Megacalanus princeps Wolfend.
Rhincalanus nasutus Giesbr.
Eucalanus elongatus (Dana).
Ætideus armatus Brady.
Undeuchæta major Giesbr.
Pseudochirella notacantha Sars.
Onchocalanus trigoniceps Sars.
Amallothrix emarginata (Farran).
Scaphocalanus magnus (T. Scott).
Metridia brevicauda Giesbr.
M. princeps Giesbr.
Pleuromamma abdominalis (Lubb.).
P. gracilis (Claus).
P. xiphias Giesbr.
Lucicutia bicornuta Wolfend.
Heterostylites longicornis (Giesbr.).
Disseta palumboi Giesbr.
Euaugaptilus laticeps Sars.
Candacia falcifera Farran (? = *magna* Sewell).

Eleven species have, so far, been recorded only in the western part of the Indian Ocean, that is, to the west of the Mid-Indian Ridge ; these species are :

Calanus finmarchicus (Gunn.).
Bathycalanus bradyi (Wolfend.).
Euœtideus giesbrechti (Cleve).
Bradyidius armatus Vanhöffen.
Euchirella rostrata (Claus).
Paraeuchœta scotti (Farran).
Onchocalanus affinis With (? = *magnus* Wolfend.).
Metridia longa (Lubb.).
Haloptilus longicornis (Claus).
H. oxycephalus (Giesbr.).
Phyllopus bidentatus Brady.

But we have already seen that the Antarctic Intermediate water fills the whole of the Arabian basin, which lies to the east of the Carlsberg Ridge, and if we include the whole of the Arabian Sea in the western area, the following additional species have been taken only in this western region of the Indian Ocean :

Eucalanus longiceps Matthews.
Gaidius tenuispinus (Sars).
Cornucalanus chelifer (Thompson).
Scaphocalanus affinis Sars.
Scolecithricella (*Amallothrix*) *valida* (Farran).
Augaptilus megalurus Giesbr.
Centraugaptilus rattrayi (T. Scott).
Arietellus setosus Giesbr.

Only three or four of these species have been taken in the eastern part of the North Indian Ocean, namely, in the Bay of Bengal, that have not been taken also in the western region ; these are :

Spinocalanus magnus Wolfend,
Lucicutia bicornuta Wolfend,
Metridia boecki Giesbr.,

and *Heterostylites major* (Dahl), if we regard this as a different species from *H. longicornis* (Giesbr.).

It thus appears that out of 96 species that have been swept southward from the North Atlantic into the Sub-Antarctic region, 42 have been able to reach the part of the Indian Ocean that lies to the north of the equator, but of these, 38 are at present known from the region to the west of India, namely, the Arabian Sea, and only 22 or 23 from the eastern region—the Bay of Bengal. Since the fauna of the Sub-Antarctic region is probably circumglobal in its distribution, we should expect to find that these North Atlantic deep-water species have also been taken in the Pacific Ocean, and this is the case regarding no less than 37 of the species that have been recorded from the Indian Ocean.

Exactly the same phenomenon can be seen in those other species that appear to have been swept directly eastward by the branch of the North Atlantic Intermediate Current that runs past the Cape of Good Hope. Among these 111 species we have some 40 that have succeeded in reaching the Indian Ocean but have not, up to the present time, been taken further east in the Pacific Ocean. Of these 40 species, 5 have been taken in the Bay of Bengal, namely :

Bathycalanus richardi Sars.
Valdiviella minor Wolfend.
V. oligarthra Steuer.
Lophothrix quadrispinosa Wolfend.
Pleuromamma indica Wolfend.

Sixteen species have been taken in the Laccadive Sea, between India and Ceylon on the east and the Maldive-Laccadive Archipalagoes on the west :

Monacilla tenera Sars,
Gaidius minutus Sars,
Pseudochirella cryptospina Sars,
P. magna (Wolfend.),
P. notacantha Sars,
Valdiviella oligartha Steuer,
Onchocalanus trigoniceps Sars,
Lophothrix quadrispinosa Wolfend.,
Scolecithricella (*Amallothrix*) *arcuata* Sars,
Scaphocalanus affinis Sars,
Cornucalanus chelifer (Thompson),
Pleuromamma indica Wolfend.,
Mesorhabdus angustus Sars,
Euaugaptilus latifrons Sars,
E. tenuispinus Sars,
Pontoptilus ovalis Sars,

and to these should be added *Candacia norvegica* Boeck, that is represented by a variety *tropica* Sewell.

In contrast to this to the west of the Maldive-Laccadive Ridge, *i.e.* on the west side of the Mid-Indian Ridge and in the Arabian Sea Basin, we have records of the capture of no less than 25 species, namely :

Gætanus curvicornis Sars.
Pseudeuchæta brevicauda Sars.
Valdiviella oligarthra Steuer.
Paraeuchæta hanseni (With).
P. withi sp. nov.
Xanthocalanus greeni Farran.
Lophothrix quadrispinosa Wolfend.
Scolecithricella (*Amallothrix*) *arcuata* Sars.
Pleuromamma indica Wolfend.
Mesorhabdus angustus Sars.
Euaugaptilus digitatus Sars.

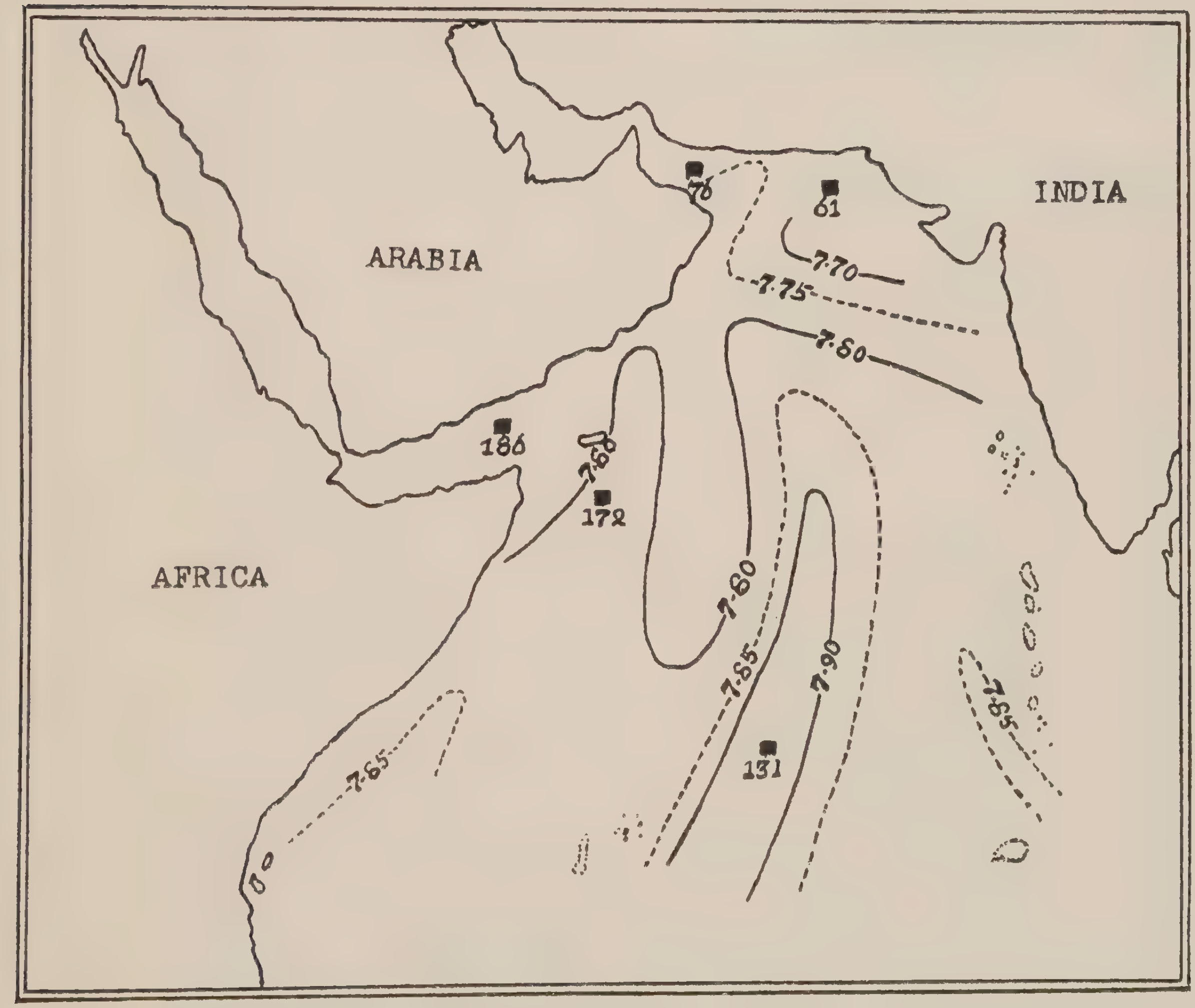
E. elongatus Sars.
E. grandicornis Sars.
E. latifrons Sars.
? *E. longicirrhus* Sars.
E. longimanus Sars.
E. penicillatus Sars.
E. tenuispinus Sars.
Haloptilus validus Sars.
Heteroptilus acutilobus Sars.
Arietellus giesbrechti Sars.
A. plumifer Sars.
Pachyptilus eurygnathus Sars.
P. lobatus Sars.
Phyllopus muticus Sars.

In the following table I have given the total number of North Atlantic species that have been taken in the three areas, from west to east, of the northern part of the Indian Ocean :

Area.	No. of Stations.	No. of N. Atlantic species.
West of Mid-Indian Ridge and Arabian Basin	6	92
Laccadive Sea	2	74
Bay of Bengal	4	41

It is extremely interesting to try and trace the distribution of the deep-dwelling Copepoda within the area investigated by the " John Murray " Expedition, and to correlate this with the different deep currents of water. Mohamed (1940) has shown that the Antarctic Intermediate water enters the north-western area of the Indian Ocean mainly on the western side ; he writes : " In the eastern regions of the area investigated this current lies below the North Indian deep current. In the central and western regions it is split up by the North Indian Deep Current into two portions, which we have designated as the upper and lower Antarctic Intermediate Currents ; in these regions the upper Antarctic Intermediate Current lies below the surface layer and above the North Indian Deep Current. Off the African coast the Antarctic Intermediate Current shows no splitting owing to the absence of the North Indian Deep Current. The horizontal distribution of the pH has shown that the Antarctic Intermediate Current enters the area of the north-western Indian Ocean mainly on the western side. It then tends to move north-eastward on account of the deflective forces of the earth's rotation, rising nearer to the surface on its way north. . . . The lower Antarctic Intermediate Current spreads widely at a depth of 2000 m. and reaches as far north as the Gulf of Oman." In the accompanying chart (Text-fig. 90) I have given the position of the various stations of the " John Murray " Expedition at which hauls of plankton were obtained and the pH distribution at a depth of 1500 m. At this depth we can clearly see the two branches of the Antarctic Intermediate Current, with a pH of 7.80 or over, moving northwards, and between them the North Indian Intermediate water, with a pH of less than 7.80, moving towards the south. Station 172 lies further to the north, but considerably further to the west than Sta. 131, and therefore, according to Mohamed, lies in the line of the main stream of Antarctic Intermediate water. Hauls were obtained at this station from depths of 2091–0 m. and 850–0 m., and both of these must have sampled the Antarctic water. In these two hauls the following species were obtained :

***Calanoides patagoniensis* Brady.
**Megacalanus princeps* Wolfend.
**Eucalanus attenuatus* (Dana).
**E. elongatus* (Dana).
**Rhincalanus nasutus* Giesbr.
Gætanus brevicornis Esterly.
**G. kruppi* Giesbr.
**G. miles* Giesbr.
**G. minor* Farran.
**G. pileatus* Farran.
**Euchirella galeata* Giesbr.
E. orientalis Sewell.



Text-fig. 90.—Showing thedisiibution of the Antarctic Intermediate Current at a depth of 1500 m., and the portion of the " John Murray t'cions 61, 76, 131 and 172.rsn

***E. pulchra* (Lubb.).
Chirundina indica Sewell.
**C. streetsi* Giesbr.
Undeuchæta bispinosa Esterly.
**Valdiviella insignis* Farran.
**Euchæta spinosa* Giesbr.
E. tenuis Esterly.
**Paraeuchæta hanseni* (With).
P. investigatoris Sewell.
P. malayensis Sewell.
**P. sarsi* Farran.
P. spinifera Esterly.
**P. tonsa* Giesbr.
P. weberi A. Scott.
**Xanthocalanus greeni* Farran.
**Onchocalanus affinis* With.
**O. trigoniceps* Sars.
**Scottocalanus securifrons* (T. Scott).
**Scaphocalanus magnus* (T. Scott).
**Lophothrix frontalis* Giesbr.
**L. quadrispinosa* Wolfend.
**Scolecithricella* (*Amallothrix*) *arcuata* Sars.
**S.* (*A.*) *emarginata* (Farran).
**S.* (*A.*) *gracilis* Sars.
**Metridia princeps* Giesbr.
**Pleuromamma abdominalis* (Lubb.).
**P. indica* Wolfend.
**P. quadrungulata* (Dahl).
**Gaussia princeps* (T. Scott).
**Lucicutia challengeri* Sewell.
**Heterorhabdus abyssalis* (Giesbr.).
**H. spinifrons* (Claus).
**Hemirhabdus grimaldii* (Richard).
**H. truncatus* (A. Scott).
**Disseta palumboi* Giesbr.
**Haloptilus chierchiæ* (Giesbr.).
**H. ornatus* (Giesbr.).
**H. oxycephalus* (Giesbr.).
**H. validus* Sars.
**Euaugaptilus elongatus* Sars.
**E. facilis* (Farran).
E. indicus Sewell.
**E. laticeps* Sars.
**E. latifrons* Sars.
? **E. longicirrhus* Sars.
* *E. longimanus* Sars.

**E. magnus* (Wolfend.).
**E. nodifrons* Sars.
**E. oblongus* Sars.
**Augaptilus longicaudatus* (Claus).
**Arietellus simplex* Sars.
**Pachyptilus eurygnathus* Sars.

Of these 64 species, as many as 54, or 84 per cent., are known to occur in the Atlantic Ocean; these are marked with an asterisk. At the same Station, but at a somewhat higher level in two hauls from 400–0 and 200–0 m., six deep-sea species were taken, namely:

Eucalanus pseudattenuatus sp. nov.
Euchirella bella Giesbr. var. *indica* Wolfend.
**E. truncata* Esterly.
Scottocalanus dauglishi Sewell.
**Pleuromamma quadrungulata* (Dahl).
**Arietellus giesbrechti* Sars.

Of these, three, marked by an asterisk, are known from the Atlantic Ocean, so that it would appear that at this depth there is a considerable admixture of Antarctic Intermediate water with the surface stratum, and to this admixture is to be attributed the presence of the three Atlantic species.

At Sta. 131 the two hauls, from 2000–0 m. and 1500–0 m. respectively, will have sampled the deep layer of Antarctic Intermediate water, and the Copepoda taken in these hauls were:

**Neocalanus gracilis* (Dana).
**N. rubustior* (Giesbr.).
**Megacalanus princeps* Wolfend.
**Eucalanus attenuatus* (Dana).
**E. elongatus* (Dana).
**Rhincalanus nasutus* Giesbr.
Gætanus brevicornis Esterly.
**G. kruppi* Giesbr.
**G. pileatus* Farran.
Euchirella bella Giesbr. var. *indica* Wolfend.
**E. galeata* Giesbr.
**E. maxima* Wolfend.
**E. pulchra* (Lubb.).
**E. truncata* Esterly.
E. venusta Giesbr.
Chirundina indica Sewell.
**C. streetsi* Giesbr.
**Pseudochirella obtusa* Sars.
Undeuchæta bispinosa Esterly.
**U. major* Giesbr.
Euchæta tenuis Esterly.
Paraeuchæta malayensis Sewell.

*P. *sarsi* Farran.
*P. *scotti* (Farran).
*P. *tonsa* Giesbr.
P. weberi A. Scott.
*P. *withi* sp. nov.
**Scottocalanus persecans* (Giesbr.).
*S. *securifrons* (T. Scott).
**Scaphocalanus magnus* (T. Scott).
**Lophothrix frontalis* Giesbr.
**Metridia princeps* Giesbr.
**Pleuromamma abdominalis* (Lubb.).
*P. *quadrungulata* (Dahl).
*P. *xiphias* (Giesbr.).
**Lucicutia bicornuta* Wolfend.
**Heterostylites longicornis* (Giesbr.).
**Heterorhabdus abyssalis* (Giesbr.).
**Hemirhabdus grimaldii* (Richard).
**Disseta palumboi* Giesbr.
**Euaugaptilus bullifer* (Giesbr.).
*E. *nodifrons* Sars.
**Haloptilus mucronatus* (Claus).
*H. *ornatus* (Giesbr.).
*H. *oxycephalus* (Giesbr.).
**Arietellus giesbrechti* Sars.

At this station out of a total of 46 species, 38, or 82·5 per cent., are known from the Atlantic Ocean; I have again indicated these species by an asterisk.

If, as I suggest, these Atlantic species have been swept eastwards in the Atlantic intermediate water and then northwards in the Antarctic Intermediate Current, and if Störmer (1933) be correct in his view that the number of species originally present in any given current of water will steadily decrease as we pass down the current away from its source, then we should expect to find that as we go northwards from Sta. 131 the number of Atlantic species will diminish. At Sta. 61 at the entrance to the Gulf of Oman the Antarctic Intermediate water forms a very clear layer between the depth of 1500 m. and the bottom; at this station two hauls were taken from 2000–0 m. and 1500–0 m., and it seems safe to assume that these hauls will have sampled the Antarctic Intermediate Current. The following deep-sea species were obtained:

**Calanus finmarchicus* (Gunn.).
**Eucalanus elongatus* (Dana).
E. pseudattenuatus sp. nov.
**Rhincalanus nasutus* Giesbr.
Gætanus antarcticus Wolfend.
*G. *curvicornis* Sars.
Euchirella bella Giesbr.
*E. *maxima* Wolfend.
**Pseudochirella notacantha* Sars.
**Pseudeuchæta brevicauda* Sars.

- **Valdiviella oligarthra* Steuer.
- **Paraeuchæta bisinuata* Sars.
- **Lophothrix humilifrons* Sars.
- *Scolecithricella* (*Amallothrix*) *indica* Sewell
- **Metridia princeps* Giesbr.
- **Lucicutia challengeri* Sewell.
- **Heterostylites longicornis* (Giesbr.).
- **Hemirhabdus truncatus* (A. Scott).
- **Mesorhabdus angustus* Sars.
- **Haloptilus chierchiæ* (Giesbr.).
- **Euaugaptilus angustus* Sars.
- **E. digitatus* Sars.
- **E. elongatus* Sars.
- **E. grandicornis* Sars.
- **E. laticeps* Sars.
- **E. latifrons* Sars.
- **E. longimanus* Sars.
- **E. magnus* (Wolfend.).
- **E. nodifrons* Sars.
- **E. oblongus* Sars.
- **E. penicillatus* Sars.
- **E. tenuispinus* Sars.
- **Centraugaptilus horridus* (Farran).
- **Pachyptilus eurygnathus* Sars.
- **P. lobatus* Sars.
- **Phyllopus muticus* Sars.

At this station we thus get only 36 deep-sea species, and of these, 32, marked with an asterisk, or 89 per cent., are known to occur in the Atlantic Ocean, and one species, *Gætanus antarcticus*, comes from the Antarctic Ocean, where Wolfenden obtained it.

Proceeding westwards still further into the Gulf, at Sta. 76 near the head of the Gulf of Oman the Antarctic Intermediate water occupies the deeper levels below about 1500 m., and in the haul from this depth to the surface we get the following species :

- **Calanoides patagoniensis* Brady,
- **Eucalanus elongatus* (Dana),
- *Euchirella bella* Giesbr.,
- **Onchocalanus affinis* With,
- **Scaphocalanus magnus* (T. Scott),
- **Metridia princeps* Giesbr.,
- **Pleuromamma indica* Wolfend.,
- **Lucicutia challengeri* Sewell,
- **Haloptilus chierchiæ* (Giesbr.),
- **Euaugaptilus longimanus* Sars,
- **E. nodifrons* Sars,
- **Centraugaptilus horridus* (Farran),
- **Phyllopus impar* Farran,
- **Pachyptilus eurygnathus* Sars,

and from the stratum above this depth in a haul from 600–0 m. we obtained the following additional species:

**Eucalanus attenuatus* (Dana).
**Euchirella maxima* Wolfend.
**Mesorhabdus angustus* Sars.
**Disseta palumboi* Giesbr.
**Haloptilus acutifrons* (Giesbr.).

Of these 19 species, 18, marked with an asterisk, are known from the Atlantic Ocean, the only exception being *Euchirella bella*, which is known from the Cape of Good Hope region. At the same station from a haul between 2500–0 m. two other species were obtained, namely *Bathycalanus bradyi* (Wolfend.) and *Gætanus antarcticus* Wolfend.; both of these species have been recorded by Wolfenden from the Antarctic region, but the former is also known from the North Atlantic.

Mohamed (1940, p. 192) has put forward the view that the upper stratum of Antarctic Intermediate water divides off the entrance to the Gulf of Aden into two branches, the western of which swings into and passes up the Gulf. If this be so, we should expect to find that at Sta. 186 in the Gulf of Aden most, at any rate, of the species present have also been taken at Stas. 131 and 172 in the Antarctic Intermediate water. The collection at this station was made in the month of May, and Mohamed has shown that at this time of the year there is a mass of water entering the Gulf at a depth of about 200 m., which appears to be Antarctic Intermediate water; below this lies a stratum, extending between 600–1000 m., which is probably outflowing Red Sea water, and finally on the bottom is a second stratum of inflowing oceanic water, which must almost certainly be Antarctic Intermediate water. Unfortunately the depths at which the deep hauls were made at this station fall either within or very near the upper limit of the outflowing Red Sea water. Even so, one might expect to find that the majority of the species taken here would prove to be the same as those taken at Stas. 131 and 172. The species recorded from this station are as follows:

**Eucalanus attenuatus* (Dana).
**E. elongatus* (Dana).
**Rhincalanus nasutus* Giesbr.
**Gætanus kruppi* Giesbr.
**Euchirella galeata* Giesbr.
**E. maxima* Wolfend.
E. orientalis Sewell.
**E. pulchra* (Lubb.).
Chirundina indica Sewell.
Undeuchæta bispinosa Esterly.
Euchæta tenuis Esterly.
Paraeuchæta investigatoris Sewell
P. weberi A. Scott.
Scottocalanus dauglishi Sewell
**Lophothrix frontalis* Giesbr.
**Pleuromamma xiphias* (Giesbr.).
**Heterorhabdus spinifrons* (Claus).
**Euaugaptilus magnus* (Wolfend.).
**Heteroptilus acutilobus* Sars

All these were obtained from depths of 575 m., 600 m. and 960 m. At a higher level in a haul from 250-0 m. examples were taken of *Euchirella bella* Giesbr. We thus have in this area 20 deep-sea species, of which 12, marked with an asterisk, are known to be Atlantic species, and the remaining 8 appear to have had their origin in the Indian Ocean or off the Cape of Good Hope.

It is thus clear that as we pass northwards along the Antarctic Intermediate Current there is, as Störmer anticipated, a gradual falling off in the number of deep-sea Copepoda, and especially of North Atlantic species ; this is seen very clearly in the following table :

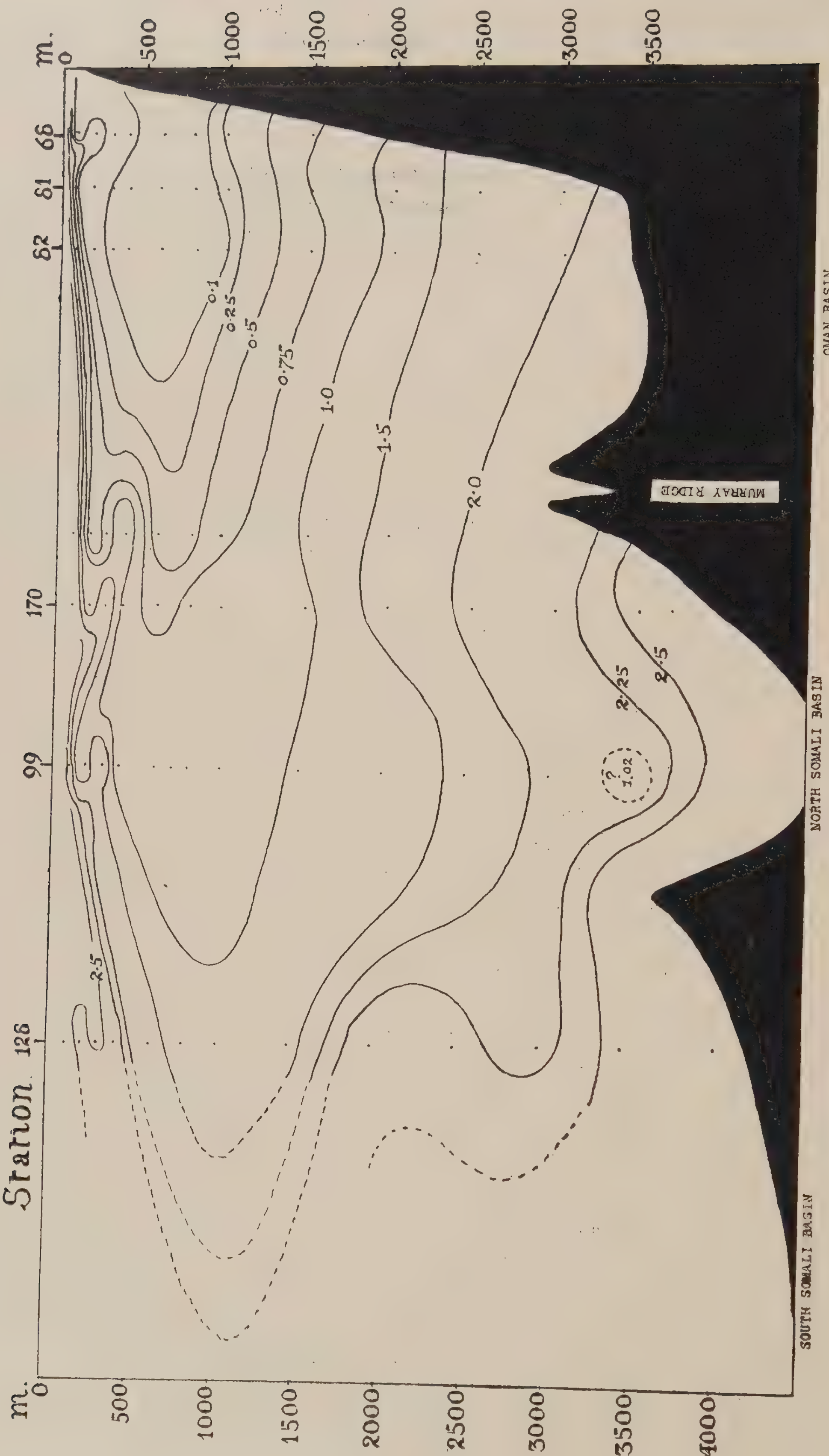
Station.	172.	131.	61.	76.	186.
North Atlantic species .	56 .	38 .	32 .	19 .	12
Indian species . . .	14 .	8 .	3 .	1 .	8
Total . . .	70 .	46 .	35 .	20 .	20

A further point that seems to be indicated is that those species that have not been taken further to the west than in Indian waters, and are presumably indigenous, appear to have difficulty in getting into the Gulf of Oman, three species only having been carried as far as the entrance to the Gulf, namely :

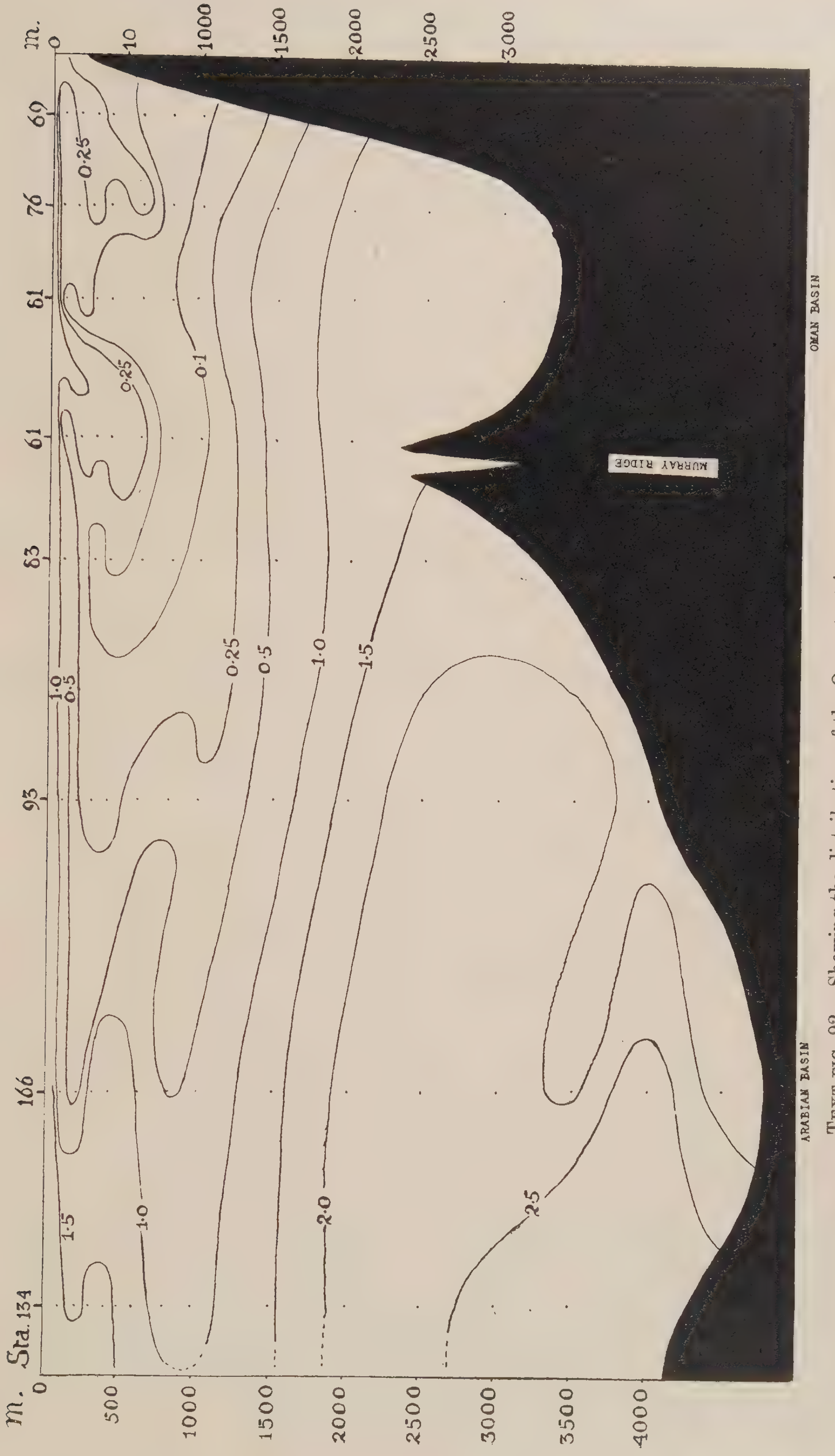
Eucalanus pseudattenuatus sp. nov.,
Euchirella bella Giesbr.,
Scolecithricella (*Amallothrix*) *indica* Sewell,

and of these only the second, *Euchirella bella* Giesbr., has reached the head of the Gulf.

The Indian Intermediate Current has its origin along the coast of Arabia and in the Gulf of Oman, and this mass of water is characterized by a low pH concentration and an extremely low oxygen-content. Mohamed (1940, p. 191) has pointed out that this mass of water " off the South Arabian and Indian coasts . . . lies immediately below the surface layer, but further west it is separated from it by the upper Antarctic Intermediate Current ; off the African coast it is practically non-existent. . . . This current, which exhibits a three-fold division in the upper levels, tends to move south-westwards on account of the deviating force of the earth's rotation and . . . sinks to greater depths on its way south until it reaches its greatest expanse at a depth of 800 m." The course taken by this current is very clearly shown in the chart of oxygen distribution (Text-figs. 91 and 92) ; at Stas. 68, 76, 81 and 82 in the Gulf of Oman this water lies immediately beneath the surface and extends down to a depth of about 1000 m., the oxygen content of the water being less than 0·1 c.c. per litre. As we trace the current southwards through Stas. 170, 99 and 128 in the series of basins on the west side of the Mid-Indian Ridge (Text-fig. 91), the current of North Indian Intermediate water can be seen extending southwards at a depth of about 1000 m., and at the same time the oxygen content steadily rises till at Sta. 128 (lat. 5° 31′ 42″ S.) in the main axis of the current this has risen to nearly 1·5 c.c. per litre. In the section through the eastern series of basins (Text-fig. 92), the North Indian Intermediate water is seen equally clearly to be passing southwards, the main mass of the current lying at about 1000 m. depth, but in this section the rise of oxygen content is not so rapid, for at Sta. 134 (lat. 2° 55′ 30″ N.) the value is



TEXT-FIG. 91.—Showing the distribution of O_2 content in a section down the western side of the Arabian Sea.



TEXT-FIG. 92.—Showing the distribution of the O_2 content in a section down the east side of the Arabian Sea.

still under 1·0 c.c. per litre. As the main mass of the current lies at a depth too great for the growth and activity of chlorophyll-bearing phyto-plankton, and in the southern part of the eastern section is clearly separated from the surface water by the upper layer of Antarctic Intermediate water, this rise of oxygen must be attributed to admixture with the water masses immediately above and below, *i.e.* with the Antarctic Intermediate water, accompanied by diffusion of the gas from one water mass to the other. At its origin the North Indian Intermediate water corresponds to the area of sea-bottom to which I have previously (Sewell, 1934) referred and which is characterized by a complete absence of life.

The deep-sea species of Copepoda that were taken at Sta. 76 at the head of the Gulf of Oman in a haul from 600–0 m. are as follows:

Calanoides patagoniensis Brady.
Eucalanus attenuatus (Dana).
E. elongatus (Dana).
Rhincalanus nasutus Giesbr.
Euchirella maxima Wolfend.
Mesorhabdus angustus Sars.
Disseta palumboi Giesbr.
Haloptilus acutifrons Giesbr.

At Sta. 61, near the entrance to the Gulf, a haul from 1000–0 m. yielded only the following species:

Eucalanus elongatus (Dana).
Rhincalanus nasutus Giesbr.
Euchirella bella Giesbr.
Lucicutia challengeri Sewell.
Euaugaptilus latifrons Sars.
E. nodifrons Sars.
Centraugaptilus horridus (Farran).
Pachyptilus eurygnathus Sars.

Combining these two results, we have present at a depth that corresponds to the North Indian Intermediate water as few as 14 deep-sea species, of which 13 are Atlantic forms, and only a single species, *Euchirella bella*, is an Indian form. This paucity of life is in marked contrast to the richness of the surface stratum, in which as many as 70 species were present, and the deeper stratum below 1500 m., in which 38 species were taken at Sta. 61 and 16 species at Sta. 76. Moreover, with the exception of *Eucalanus attenuatus* (Dana) and *Disseta palumboi* Giesbr., all the species that were taken in the North Indian water are also present in the deeper water of the Antarctic Intermediate Current. It seems justifiable to conclude that at its origin the North Indian Intermediate water, like the sea floor, is for all practical purposes devoid of life, so far as the Copepoda are concerned, and that the few species present have been carried in from the deeper and richer Antarctic water by diffusion or turbulence.

Outside the Oman basin at Sta. 96 in the Arabian Basin a haul was taken with the self-closing net between 645 and 400 m., in the middle of the main mass of North Indian Intermediate water; here the following species were obtained:

**Megacalanus princeps* Wolfend.
**Eucalanus attenuatus* (Dana).
**E. elongatus* (Dana).
E. pseudattenuatus sp. nov.
**Rhincalanus nasutus* Giesbr.
**Gætanus kruppi* Giesbr.
**G. miles* Giesbr.
**G. pileatus* Farran.
Euchirella bella Giesbr.
**E. galeata* Giesbr.
E. orientalis Sewell.
Chirundina indica Sewell.
**C. streetsi* Giesbr.
**Pseudochirella magna* (Wolfend.).
Undeuchæta bispinosa Esterly.
Euchæta tenuis Esterly.
Paraeuchæta investigatoris Sewell.
**P. tonsa* Giesbr.
P. weberi A. Scott.
**Onchocalanus trigoniceps* Sars.
Scottocalanus dauglishi Sewell.
**Scaphocalanus magnus* (T. Scott).
**Lophothrix frontalis* Giesbr.
Amallothrix indica Sewell.
**Metridia princeps* Giesbr.
**Pleuromamma xiphias* (Giesbr.).
**Lucicutia challengeri* Sewell.
**Heterorhabdus abyssalis* (Giesbr.).
**H. spinifrons* (Claus).
**Disseta palumboi* Giesbr.
**Haloptilus validus* Sars.
**Euaugaptilus nodifrons* Sars.
**E. magnus* (Wolfend.).
**Arietellus plumifer* Sars.
**A. simplex* Sars.

The total number of deep-sea species has now increased to 35, and of these, 25 are Atlantic forms and are marked with an asterisk. No less than 23 of these 25 Atlantic forms have been recorded from the Antarctic Intermediate water at Sta. 172 and 16 from Sta. 131. It thus seems justifiable to conclude that this increase in the number of species as we pass away from the source of this North Indian Intermediate water is, like the increase in the amount of dissolved oxygen, due to admixture with the Antarctic Intermediate water.

I have already drawn attention to the fact that in these Indian waters we find a number of species that have not, up to the present time, been taken in the Atlantic Ocean, in spite of the great amount of work that has been carried out there ; I believe that these species have originated in the Indian Ocean itself. The full list of these species is as follows :

†*Calanoides natalis* Brady,
†*Bradycalanus gigas* sp. nov.,
?*B. typicus* A. Scott,
†*Eucalanus pseudattenuatus* sp. nov.,
Undinopsis tropicus Wolfend. (? = *Bradyidius armatus* (Brady)),
†*Chirundina indica* Sewell,
Gætanus brevicornis Esterly,
Euchirella bella Giesbr.,
†*E. orientalis* Sewell,
E. venustus Giesbr.,
Undeuchæta bispinosa Esterly,
†*Valdiviella ignota* Sewell,
†*Euchæta arabica* Sciacchitano,
E. tenuis Esterly,
Paraeuchæta gracillicauda A. Scott,
†*P. investigatoris* Sewell,
P. malayensis Sewell,
P. spinifera Esterly,
P. tuberculata A. Scott,
P. weberi A. Scott,
†*Cornucalanus indicus* Sewell,
†*Xanthocalanus gigas* Sciacchitano,
†*Scottocalanus dauglishi* Sewell,
S. farrani A. Scott,
†*S. investigatoris* Sewell,
S. thomasi A. Scott,
Scaphocalanus elongatus A. Scott,
†*Amallothrix indica* Sewell,
†*Amallophora coistata* Sciacchitano,
†*Lucicutia aurita* Cleve,
†*L. bradyana* Cleve,
†*Euaugaptilus indicus* Sewell,

and perhaps to these may be added *Heterorhabdus tanneri* Giesbr. : but this last species may have originated in the water of the West Wind Drift (*vide infra* p. 570). Several of these species, marked in the above list with a dagger, have not, up to the present time, been recorded from any other region, and it is possible that they are endemic.

Euchæta arabica Sciacchitano, *Amallophora coistata* Sciacchitano and *Xanthocalanus gigas* Sciacchitano have only been recorded from the Gulf of Aden. *Lucicutia aurita* Cleve and *L. bradyana* Cleve are at present known only from the Cape of Good Hope region, and *Calanoides natalis* Brady from the coast of Natal. *Bradycalanus gigas* sp. nov. and *Eucalanus pseudattenuatus* sp. nov. have so far been taken only in the

Arabian Sea, *Chirundina indica* Sewell and *Amallothrix indica* Sewell in the Arabian Sea and Laccadive Sea, *Scottocalanus dauglishi* Sewell and *Euaugaptilus indicus* Sewell in the Arabian Sea, Laccadive Sea and Bay of Bengal, and *Euchirella orientalis* Sewell and *Paraeuchæta investigatoris* Sewell in the Arabian Sea and the Bay of Bengal, but so far not in the Laccadive Sea; *Scottocalanus investigatoris* Sewell* has been taken in the Laccadive Sea only and *Valdiviella ignota* Sewell and *Cornucalanus indicus* Sewell in the Bay of Bengal only. It would thus appear that the main centre of production of these Indian species lies on the west side of the Indian Ocean or in the Arabian Sea, and, in addition, the local conditions that are present in this region appear to be responsible for the evolution of small or depauperized forms of certain other species, such as the "dwarf" race of *Pleuromamma xiphias* (Giesbr.) that is found in the western part of the Arabian Sea and the Gulf of Aden (*vide* Steuer, 1932, p. 70). In the Gulf of Oman we captured only one Indian species, namely, *Euchirella bella* Giesbr., but as we follow the North Indian intermediate water southwards the number of Indian species that were taken greatly increases. At Sta. 96 in a haul with the self-closing net between 645 and 400 m., which must have sampled the North Indian water, we obtained no less than 10 species, namely:

Eucalanus pseudattenuatus sp. nov.
Euchirella bella Giesbr.
E. orientalis Sewell.
Chirundina indica Sewell.
Undeuchæta bispinosa Esterly.
Euchæta tenuis Esterly.
Paraeuchæta investigatoris Sewell.
P. weberi A. Scott.
Scottocalanus dauglishi Sewell.
Amallothrix indica Sewell.

Still further south at Sta. 131 in a haul from 1500–0 m., which again must have sampled the North Indian Intermediate water, we obtained 8 Indian species, namely:

Euchirella bella Giesbr.
E. venusta Giesbr.
Chirundina indica Sewell.
Undeuchæta bispinosa Esterly.
Euchæta tenuis Esterly.
Paraeuchæta malayensis Sewell.
P. weberi A. Scott.
Gætanus brevicornis Esterly.

It appears probable that, although there is some difficulty in the way of the dispersal of these Arabian Sea species eastward into the Laccadive Sea and the Bay of Bengal, some at any rate have been able to find their way there. Between the Arabian Sea and the Laccadive Sea to a point just south of the equator lies the barrier of the Laccadive and Maldive Archipelagoes, but moderately deep channels run between the various atolls.

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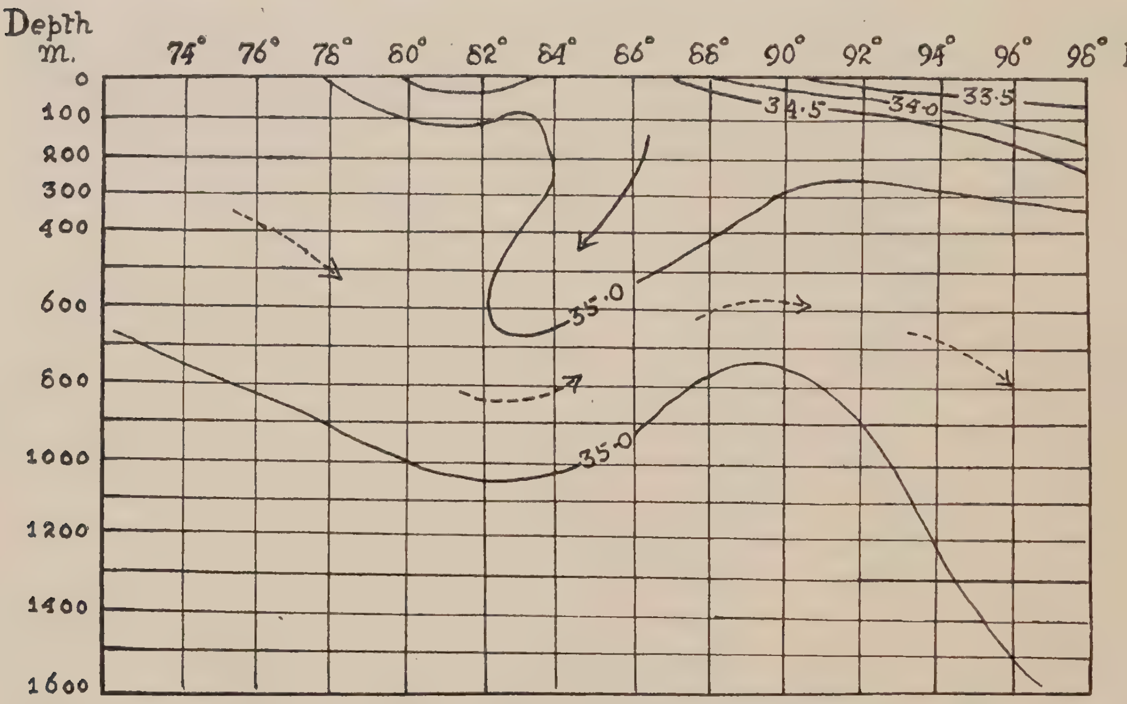
* Farran (1936, p. 101) has described *Scottacalanus australis* ♀ from the Great Barrier Reef and suggested the possiblity that this is the female of *S. investigatoris* Sewell, that is known only from the male.

One of these is Kardiva Channel, in which, at Sta. 145, we carried out a series of observations ; here we obtained 6 Indian species, namely :

Euchirella bella Giesbr.
E. orientalis Sewell.
Chirundina indica Sewell.
Undeuchæta bispinosa Esterly.
Euchæta tenuis Esterly.
Scottocalanus dauglishi Sewell.

The stratum from which these species were taken at this station was the upper 500 m. In a previous paper (Sewell, 1932*b*, p. 374), I have pointed out that a study of the isohalines from west to east across the Laccadive Sea and Bay of Bengal suggests that between lats. 1° to 10° N. there is a mass of water, probably a part of the Contra-equatorial Current, that at its western side extends downwards from the surface to about 600 m., and that this is flowing eastward across the mouth of the Laccadive Sea and past Ceylon, till off the south-east corner of this island this current becomes split into two streams by a current flowing out of the Bay of Bengal at a depth of some 600 m. ; the upper branch passes into the Bay of Bengal, and the lower continues eastward and gradually sinks till, in lat. 96° E., it extends from 350 m. down to about 1500 m. (*vide* Text-fig. 93), and it was from this mass of water that the Indian species mentioned above were taken in the Laccadive Sea in a depth of 366 m. and in the Bay of Bengal in 766 m.



Text-fig. 93.—Showing the isohalines from West to East across the mouths of the Laccadive Sea and Bay of Bengal between Latitudes 1° and 10° N. (From Sewell, 1932.)

The ultimate distribution of these Indian species of planktonic Copepoda will be dependent on the course of the North Indian Intermediate Current. Most of the hydrographic work that has been carried out in the Indian Ocean has been concerned with the region lying to the west of the Mid-Indian Ridge, and there is a considerable divergence of opinion regarding the distance to the south of the equator to which this current can be traced. Thomsen (1933) concluded that the mass of the North Indian Intermediate water, with a salinity of more than 34·80‰, did not extend beyond a line drawn from the north end of Madagascar to Ceylon. Clowes and Deacon (1935) trace it as far as lat. 20° S. in the Mozambique Channel at a depth of about 1500 m. where it meets the eastward current of North Atlantic Intermediate water, but they are of the opinion that the Indian Intermediate water flows much further southwards, sandwiched between the Atlantic water and the Antarctic Intermediate water, and Deacon (1937, p. 97) suggests that the volume and salinity of the North Indian Intermediate Current are subject to large variations, possibly related to current differences brought about by the changes of the monsoon winds and variations in the south equatorial current. If this Indian water reaches as far south as this on the west side of the Indian Ocean south of the equator, where the strength of the current is least, it can, I think, safely be assumed that in the eastern part of the ocean the current will be greater and extend further southward. One source of origin of this Indian Intermediate water lies at the head of the Arabian Sea, and the outflow from the Arabian Basin is, as we have seen, pushed away from the African coast by the northwardly flowing Antarctic Intermediate water; at the same time it seems likely that the configuration of the ocean floor will also tend to displace the Indian water eastward in much the same manner as the Mid-Atlantic Ridge deflects the Arctic water into the eastern series of basins (*vide supra*, Text-fig. 89, p. 518). It is also probable that at least at certain seasons of the year the mass of North Indian Intermediate water flowing out of the Arabian Sea is augmented by an outflow of water from the Andaman Sea and Bay of Bengal (*vide* Sewell, 1932). Deacon (1937, p. 97), however, doubts the existence of this latter source; he states that "the observations made by the 'Snellius' and 'Dana' also show that no deep current comparable with that which flows from the Arabian Sea and its adjoining gulfs is formed in the north-eastern part of the ocean (Möller, 1933, p. 234), and the salinity distribution in the cross section from west to east across the ocean in 8 N. to 2 S. shows that the deep water formed in the western part of the ocean spreads towards the east." The mass of water of the North Indian Intermediate Current will, under the influence of the earth's rotation, have imparted to it an easterly trend that will carry it to the south of Australia and then, as Möller (1929) has suggested, eastward into the Pacific Ocean.

The south-western region of the Pacific Ocean appears to be filled in its deeper levels with water that has several different sources of origin well outside the geographical limits of the ocean itself. Both Sverdrup (1931) and Schott (1935) are of the opinion that the water of the South Pacific Ocean at a depth of 1500 m. is an importation from the depths of the Indian Ocean, and even further westward from the Atlantic Ocean. Deacon (1937, p. 98) has summarized our knowledge up to the time of his report, and he shows that there are indications in the south-eastern part of the Indian Ocean of a mass of water that is derived partly from the Indian Intermediate Current that is moving towards the south-east and is becoming mixed with the Antarctic bottom water and partly from the eastward continuation of the current of North Atlantic water that, as we have seen, swings eastward from the South Atlantic past the Cape of Good Hope and on across the southern part of the Indian Ocean. Deacon (*loc. cit.*, p. 101) has also pointed out that as we pass eastward from the region to the south of Australia into the Pacific Ocean, "the bottom topography south of New Zealand is so irregular that the eastward current must be interrupted by numerous eddy movements, which will cause the salinity to be lowered by turbulent mixing with the less saline waters in the shallower and deeper strata"; and such mixing of the water masses must be accompanied by an equal mixing of the plankton. The south-west region of the Pacific Ocean has undergone, and, according to the most recent investigations, is still undergoing great orographical changes. Umbgrove (1938) remarks: "We conclude from the occurrence of bathyal and abyssal sediments among mesozoic rocks of many an island that, during the Mesozoic, deep-sea basins must have existed within the bounds of the present Archipélago. . . . The marine sediments we know from the Tertiary of the entire Archipelago are littoral and neritic rocks, deposited in a shallow sea. . . . Even in the areas where a very intensive Miocene folding took place the facies of the sediments shows that the bottom was never situated at a great depth below the level of the sea. From these facts alone it is evident that the present deep-sea relief of the East Indian Archipelago is a characteristic that must have originated during the recent geological past." Kuenen (1935) places the most important part of the movement in the Pleistocene. He remarks (*loc. cit.*, p. 50): "The general conclusion, therefore, is that the deep-sea troughs and geanticlines date from the end of the Tertiary and are still in course of further development." If this view be correct, it seems clear that these deep-sea basins must have become populated by their planktonic fauna in equally recent times.

As in the other two oceans, we have in the Pacific beneath the West Wind Drift, in about lat. 40° S., a mass of water that sinks down and turns northwards, where it forms the South Polar or Antarctic Intermediate layer, lying, according to Defant (1930), between 1000 and 1500 m. This Antarctic Intermediate water on the east side of New Zealand can be traced as far as 0°–16° N., but the strength of the current seems to increase as we pass eastwards first to the central part of the ocean and then to the south-east region (*vide* Deacon, 1937, p. 69). The work of the "Snellius" expedition (*vide* van Riel, 1934, 1938) has, however, shown that certain basins in the Malay Archipelago, namely, the Beroe, Banda, Wettar and Sawoe basins, seem to be filled with water that has flowed in from the east at a depth of less than 1500 m. (*vide* Text-fig. 73, p. 337). In consequence this area must be included in the Pacific region, and not, as I previously have done (Sewell, 1929, 1932), in the Indian Ocean.

If the plankton has been transported along all these various currents into the Pacific we should be able to find evidence of the contribution that each has made. Thanks to the work of Brady (1899), Cleve (1901), A. Scott (1909), Früchtl (1924), Farran (1925 and 1936), Wilson (1942) and Vervoort (1946) we now possess an extensive knowledge of the Copepod fauna of the south-western area, and I have been able to collate records of some 200 deep-sea species, of which the Atlantic Ocean appears to have contributed as many as 154, namely:

†*Calanus finmarchicus* (Gunn.).
? *C. helgolandicus* (Claus).
†*C. tenuicornis* Dana.
C. tonsus Brady.
Calanoides brevicornis (Lubb.) (= *C. carinatus* (Kröyer)).
†*Neocalanus gracilis* (Dana).

†*N. robustior* (Giesbr.).
†*Megacalanus princeps* Wolfend.
†*Bathycalanus bradyi* Wolfend.
†*B. richardi* Sars.
†*Ctenocalanus vanus* Giesbr.
†*Eucalanus attenuatus* (Dana).
†*E. elongatus* (Dana).
†*E. longiceps* Matthews (= *acus* Farran).
†*Rhincalanus nasutus* Giesbr.
Spinocalanus abyssalis Giesbr.
S. hirtus Sars.
†*S. magnus* Wolfend. (=*Latifrons* Sars).
S. spinosus Farran. (=*Norridus* Wolf.).
S. validus Sars.
Mimocalanus cultrifer Farran.
Monacilla typica Sars. (=*dubia* A. Scott).
†*Euætideus giesbrechti* (Cleve).
†*Ætideus armatus* (Boeck).
Æ. bradyi A. Scott.
Ætideopsis multiserrata (Wolfend.) (= *rostrata*, A. Scott, *non* Sars).
†*Bradyidius armatus* (Vanhöffen) (= *Undinopsis similis* Sars).
†*Chiridius poppei* Giesbr.
†*C. gracilis* Farran.
†*Chirundina streetsi* Giesbr.
Pseudotharybdis zetlandicus T. Scott.
†*Gætanus armiger* Giesbr.
†*G. kruppi* Giesbr.
†*G. latifrons* Sars.
†*G. miles* Giesbr.
†*G. minor* Farran.
†*G. pileatus* Farran.
†*G. rectus* Wolfend. (= *brevicornis* Esterly and *hamatus* A. Scott).
Gaidius affinis Sars.
G. notacanthus Sars.
†*G. tenuispinus* Sars (= *similis* T. Scott).
Euchirella amœna Giesbr.
†*E. brevis* Sars.
†*E. curticauda* Giesbr.
†*E. galeata* Giesbr.
†*E. maxima* Wolfend.
†*E. messinensis* (Claus).
†*E. pulchra* (Lubb.).
†*E. rostrata* (Claus).
†*Undeuchæta major* Giesbr.
†*U. plumosa* (Lubb.) (= *minora* Sars).
†*Pseudochirella obtusa* Sars (= *abyssalis* With, *dubia* A. Scott).

†*Valdiviella brevicornis* Sars.
†*V. insignis* Farran.
Euchæta pubera Sars.
†*E. spinosa* Giesbr.
?†*Paraeuchæta barbata* Brady.
†*P. bisinuata* Sars.
†*P. sarsi* Farran.
†*P. tonsa* Giesbr.
Chiridiella macrodactyla Sars.
†*Phænna spinifera* Claus.
Xanthocalanus agilis Giesbr.
†*Onchocalanus affinis* With (= *hirtipes* Sars).
O. cristatus (Wolfend.).
†*Cornucalanus simplex* Wolfend.
Amallophora typica T. Scott.
Heteramalla dubia (T. Scott).
†*Scottocalanus helenae* (Lubb.).
†*S. persecans* (Giesbr.).
†*S. securifrons* (T. Scott).
†*Lophothrix frontalis* Giesbr.
L. latipes (T. Scott) (= *Scolecithrix acuta* (Wolfend.)).
Scaphocalanus curtus (Farran).
S. echinatus (Farran).
†*S. magnus* (T. Scott).
S. major (T. Scott).
†*S. medius* Sars (= *gracilipes* Farran, ? *major* (T. Scott)).
†*Scolecithricella abyssalis* (Giesbr.).
†*S. auropecten* (Giesbr.).
†*S. ctenopus* (Giesbr.).
S. dentata (Giesbr.).
S. longicornis (T. Scott).
S. ovata (Farran).
S. profunda (Giesbr.).
†*S. tenuipes* (T. Scott).
†*S. tenuiserrata* (Giesbr.).
S. vittata (Giesbr.).
Amallothrix curticauda (A. Scott).
†*A. emarginata* (Farran).
†*A. gracilis* (Sars).
A. obtusifrons Sars (? = *Scolecithricella tydemani* A. Scott).
†*A. valida* (Farran).
Temoropia mayumbæensis T. Scott.
†*Metridia bœcki* Giesbr.
†*M. brevicauda* Giesbr.
M. lucens Boeck.
†*M. macrura* Sars.

†*M. princeps* Giesbr.
†*M. venusta* Giesbr.
†*Pleuromamma abdominalis* (Lubb.).
†*P. gracilis* (Claus).
†*P. borealis* (Dahl).
P. piseki Farran (= *gracilis* (Claus)).
†*P. robusta* (F. Dahl).
†*P. xiphias* (Giesbr.).
†*Lucicutia atlantica* Wolfend. (= *gracilis* Sars).
L. bicornuta Wolfend.
†*L. challengeri* Sewell.
†*L. clausi* (Giesbr.).
L. gemina Farran.
L. longiserrata (Giesbr.).
†*L. lucida* Farran (= *pera* A. Scott).
†*L. maxima* Steuer.
†*L. ovalis* Wolfend.
†*Candacia falcifera* Farran (? = *magna* Sewell).
†*Heterorhabdus abyssalis* (Giesbr.) (? = *norvegicus* (Boeck)).
†*H. clausi* (Giesbr.).
H. norvegicus (Boeck).
†*H. papilliger* (Claus).
†*H. spinifrons* (Claus).
†*Heterostylites longicornis* (Giesbr.).
†*Hemirhabdus grimaldii* (Richard).
†*H. truncatus* (A. Scott) (= *latus* Sars).
†*Disseta palumboi* Giesbr.
†*Augaptilus longicaudatus* (Claus).
†*A. megalurus* Giesbr.
†*Euaugaptilus angustus* Sars.
†*E. bullifer* (Giesbr.).
†*E. facilis* (Farran).
†*E. filigerus* (Claus).
†*E. hecticus* (Giesbr.).
†*E. laticeps* Sars.
†*E. magnus* (Wolfend.) (= *validus* A. Scott).
†*E. nodifrons* Sars.
†*E. oblongus* Sars.
E. palumboi Giesbr.
E. spinifrons Sars.
E. squamatus Giesbr.
†*Haloptilus acutifrons* (Giesbr.).
H. angusticeps Sars.
†*H. chierchiæ* Giesbr.
†*H. longicornis* (Claus).
†*H. mucronatus* (Claus).

†*H. ornatus* (Giesbr.).
H. plumosus (Claus).
H. spiniceps (Giesbr.).
Arietellus aculeatus (T. Scott) (= *armatus* Wolfend.).
†*A. setosus* Giesbr.
†*A. simplex* Sars.
†*Phyllopus bidentatus* Brady.
P. helgæ Farran.
†*P. impar* Farran.
Mormonilla phasma Giesbr.

It is probable that further researches will reveal in this region of the Pacific Ocean several other species that have been reported up to the present time from the Atlantic, Indian and south-east Pacific areas, namely :

†*Calanus propinquus* Brady.
†*Calanoides patagoniensis* Brady.
†*Euchirella truncata* Esterly.
†*Valdiviella minor* Wolfenden.
†*Lophothrix humilifrons* Sars.
†*Metridia longa* Lubb.
†*Pleuromamma quadrungulata* (Dahl).
†*Gaussia princeps* (T. Scott).
†*Heterorhabdus vipera* (Giesbr.).
†*Haloptilus oxycephalus* (Giesbr.).
†*Centraugaptilus horridus* (Farran) (= *pyramidalis* Esterly).
†*C. rattrayi* (T. Scott) (= *macrodus* Esterly).

We thus have as many as 166 Atlantic species that appear to have been carried eastward from the Atlantic Ocean into the South-west Pacific region, and of these, 118, marked with a †, have been taken in the Indian Ocean. It is probable that the main transportation of species from the Atlantic Ocean into the Pacific Ocean, as into the Indian Ocean, has been along the easterly branch of the North Atlantic Intermediate current, which, as we have seen, passes across the southern region of the Indian Ocean into the Pacific, and that from this current they have been carried into the Antarctic Intermediate water and so have been swept northwards into both Indian and Pacific Oceans, or, having been carried into the Indian Ocean, they may have passed into the North Indian Intermediate Current and so have reached the south-west Pacific area. A smaller number of Atlantic species may have also followed the more southerly route through the Antarctic region ; there are some 33 such species, namely :

Calanus finmarchicus (Gunn.),
Megacalanus princeps Wolfend.,
Eucalanus elongatus (Dana),
E. longiceps Matthews (? = *acus* Farran),
Rhincalanus nasutus Giesbr.,
Spinocalanus magnus Wolfend.,
Euætideus giesbrechti (Cleve),

Ætideus armatus (Boeck),
Bradyideus armatus (Vanhöffen),
Gaidius tenuispinus Sars,
Undeuchæta major Giesbr.,
Onchocalanus affinis With,
Scaphocalanus magnus (T. Scott),
Amallothrix emarginata Farran,
A. valida (Farran),
Metridia boecki Giesbr.,
M. brevicauda Giesbr.,
M. princeps Giesbr.,
Pleuromamma abdominalis (Lubb.),
P. borealis (Dahl),
P. gracilis (Claus),
P. robusta (F. Dahl),
P. xiphias (Giesbr.),
Lucicutia bicornuta Wolfend.,
L. magna Wolfend.,
Candacia falcifera Farran,
Heterostylites longicornis (Giesbr.) (= *major* (Dahl)),
Disseta palumboi Giesbr.,
Euaugaptilus laticeps Sars,
Augaptilus megalurus Giesbr.,
Haloptilus longicornis (Claus),
Arietellus setosus Giesbr.,
Phyllopus bidentatus Brady,

and 11 Atlantic species definitely appear to have passed eastward from the Atlantic to the Pacific by this southerly route, since they have not as yet been recorded from the Indian Ocean, namely :

Calanus tonsus Brady.
Spinocalanus abyssalis Giesbr.
S. spinosus Farran.
Scaphocalanus echinatus (Farran).
Onchocalanus cristatus Wolfend.
Scolecithricella ovata (Farran).
Lucicutia grandis (Giesbr.).
Metridia lucens Boeck.
Haloptilus spiniceps (Giesbr.).
? *Phyllopus helgæ* Farran.
Mormonilla phasma Giesbr.

In attributing the distribution of these species to the southern Antarctic route I have assumed that the Antarctic fauna is a circum-polar one, and that from these southerly latitudes species can have been swept towards the equator in either the Antarctic Intermediate Current or the Antarctic Bottom Drift.

We are thus left with some 34 species that have been recorded from both the Atlantic and the South-west Pacific areas but from nowhere in between; these species are as follows:

? *Calanus helgolandicus* (Claus).*
Spinocalanus validus Sars.
S. hirtus Sars.
Mimocalanus cultrifer Farran.
Monacilla typica Sars.
Ætideus bradyi A. Scott.
Ætideopsis multiserrata (Wolfend.).
Pseudotharybdis zetlandicus T. Scott.
Gaidius affinis Sars.
G. notacanthus Sars.
Euchirella amœna Giesbr.
Chiridiella macrodactyla Sars.
Euchæta pubera Sars.
Xanthocalanus agilis Giesbr.
Amallophora typica T. Scott.
Heteramalla dubia T. Scott.
Lophothrix latipes T. Scott.
Scaphocalanus curtus (Farran).
S. major (T. Scott).
Scolecithricella dentata (Giesbr.).
S. longicornis (T. Scott).
S. profunda (Giesbr.).
S. vittata (Giesbr.).
Amallothrix curticauda (A. Scott).
A. obtusifrons Sars.
Lucicutia gemina Farran.
L. longiserrata (Giesbr.).
L. lucida Farran.
Euaugaptilus palumboi Giesbr.
E. spinifrons Sars.
E. squamatus
Haloptilus angusticeps Sars.
H. plumosus (Claus).
Arietellus aculeatus (T. Scott).

Some doubt must remain whether these 34 species actually originated in the Atlantic Ocean, and have been carried into the Pacific Ocean along the easterly flowing branch of the North Atlantic Intermediate Current, without getting caught up in the Antarctic Intermediate Current in the Indian Ocean, and so have what at present appears to be a discontinuous distribution, since further investigations in the Indian or Southern Oceans may reveal their presence there also; or, alternatively, whether they were in existence in the Atlantic Ocean in Tertiary times, and were swept from thence into the Pacific Ocean at a time when these two oceans were connected by a channel across Central America. Other possible explanations of their distribution is that they have originated in the Pacific Ocean and have been swept eastward past Cape Horn into the South Atlantic Ocean, and then have been carried northwards in the Antarctic Intermediate Current, or that in the Tertiary period they were carried westward by the Tethys Sea. Neither of these two last routes seems to be very likely, for in the case of the first the latest work by Deacon (1937, p. 104) indicates that " the highly saline current from the Indian and Atlantic Oceans is turned towards the north as it approaches the western end of the Drake Passage. . . . The northward movement appears to bring about a large reduction in the volume of the deep water flowing towards the east, and in spite of some indications to the contrary it seems that not more than a comparatively small volume of Indian and Atlantic waters which form the eastward current can enter the Atlantic through the Drake Passage." He further (*loc. cit.*, p. 108) concludes that although the deep water of the Scotia Sea is a comprehensive mixture of Atlantic, Indian and Pacific waters, " it also appears to contain Atlantic water from a direct southward movement over the northern arm of the Scotia Arc and in the lower part of the layer, Weddell Sea deep water which has been formed from a westward movement of Atlantic and Indian deep waters along the Antarctic slope." Such a movement of water is not likely to carry plankton from the Pacific Ocean into the tropical and northern Atlantic Ocean. If the Tethys Sea in times past provided the highway for these species to spread westward from the Pacific to the Atlantic Ocean, we might perhaps expect to find that some of these species would be present to-day in the Mediterranean Sea, though this expectation will depend on the view that we hold regarding the succession of events in the Mediterranean Sea during the last Glacial Period (*vide supra*, p. 473). A comparison of the above list of species with that of the Mediterranean Plankton (*vide supra*, p. 507) reveals that only 6 or 7 species are common to both lists, namely:

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* The presence of this species in the south-west Pacific was recorded by Brady, but Sars (1901–3, p. 12) has put forward the view that this record is a false one and is probably due to confusion with another species; *C. helgolandicus* has, however, been recorded more recently by Wilson (1942) from the south-east Pacific area.

? *Calanus helgolandicus* (Claus).
Xanthocalanus agilis Giesbr.
Scolecithricella dentata (Giesbr.).
S. profunda (Giesbr.).
S. vittata (Giesbr.).
Haloptilus angusticeps Sars.
H. plumosus (Claus).

If, on the other hand, the connection of the two oceans across Central America were responsible for the present distribution, we might reasonably expect to find that the majority of these species would still be found inhabiting the eastern Pacific region, but there are again only 7 such, namely:

Calanus helgolandicus (Claus),
Ætideus bradyi A. Scott,
Gaidius affinis Sars,
Euchirella amœna Giesbr.,

Heteramalla dubia T. Scott,
Euaugaptilus palumboi Giesbr.,
? *Lophothrix latipes* T. Scott,

and this last species is doubtful.

I have already (*vide supra*, p. 540) given a list of 30 species that appear to have had their origin in the Indian Ocean, since none of them has as yet been taken in the Atlantic Ocean, and the presence of any of these in the south-west or west Pacific region may well be attributed to the movement of the Indian Intermediate Current. As many as 12 or 14 of these Indian species have apparently been able to survive this transportation and have been recorded from the Pacific Ocean, namely:

? *Bradycalanus typicus* A. Scott.
Undinopsis tropicus Wolfend.
Euchirella bella Giesbr.
E. venusta Giesbr.
Euchæta tenuis Esterly.
Paraeuchæta gracillicauda A. Scott.
P. investigatoris Sewell.
P. malayensis Sewell.
P. spinifera Esterly.
P. tuberculata A. Scott.
P. weberi A. Scott.
? *Scottocalanus investigatoris* Sewell (? = *australis* Farran).
S. farrani A. Scott.
S. thomasi A. Scott.

These have all been recorded from the south-west Pacific region and to these should, in all probability, be added—

Gætanus brevicornis Esterly,
Undeuchæta bispinosa Esterly,
? *Heterorhabdus tanneri* (Giesbr.),

which have been taken in the east Pacific region, though still unknown from the south-west area. Reference to A. Scott's report on the "Siboga" collections shows that the great majority of the examples of the above species were taken in the basins of the Malay Archipelago in depths between 1500 and 2000 m. which are filled (*vide supra*, p. 335) by water that is flowing in from the Pacific Ocean at about this depth, and reference to the chart given by Defant (1928, p. 485, fig. 29) indicates that this water is probably derived from the Antarctic Intermediate Current, though immediately below the Antarctic Intermediate water at about this depth a slight rise in the temperature of the water suggests that there is a flow of Pacific deep water towards the south (*vide* Deacon, 1937, p. 100).

A number of species appear to have had their origin in the south-west Pacific area, since up to the present time they have not been recorded from either the Atlantic or the

Indian Oceans : it is possible that further exploration of the Indian Ocean, and especially of its south-eastern region, may reveal their presence there. These species are as follows :

? *Bradycalanus typicus* A. Scott.*
Tanyrhinus naso Farran.
Euætideus acutus Farran.
Monacilla dubia A. Scott.
Oxycalanus semispinus A. Scott.
Gaidiopsis crassirostris A. Scott.
Euchirella dentata A. Scott.
E. dubia A. Scott.
E. granulata A. Scott.
Undeuchæta intermedia A. Scott.
Euchæta russelli Farran.
Paraeuchæta dentata A. Scott.
P. propinqua Esterly.
P. sibogæ A. Scott.
Xanthocalanus squamatus Farran.
Bradycalanus gigas A. Scott.
? *Scottocalanus australis* Farran (? = *investigatoris* Sewell).
S. longispinus A. Scott.
S. sedatus Farran.
S. setosus A. Scott.
S. terranovæ Farran.
Scolecocalanus galeatus Farran.
S. lobatus Farran.
Scolecithricella longifurca (Giesbrecht).
Lucicutia philyra A. Scott.
L. pera A. Scott.
Disseta scopularis (Brady).
Euaugaptilus placitus A. Scott.
Paraugaptilus similis A. Scott.
Phyllopus giesbrechti A. Scott.
Bathypontia spinifera A. Scott.
Neopontia typica A. Scott.

The great majority of the above species have not, up to the present time, been recorded from any other area and may be regarded as endemic ; the exceptions to this are—

Euchirella granulata A. Scott,
Paraeuchæta propinqua Esterly,
Scolecithricella longifurca (Giesbr.),

which have been recorded from the east Pacific region, and perhaps to these should be added *Disseta scopularis* (Brady), which was originally described from the North-west Pacific area and which may be represented in the north-east Pacific region by *Disseta*

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* A young example that appears to belong to the genus *Bradycalanus* A. Scott was, as noted above (p. 330), taken by the " John Murray " Expedition in Indian waters and may be a young stage of *B. typicus* A. Scott.

maxima Esterly, for *scopularis* is known only from the male and *maxima* only from the female.

There seems to be somewhat less movement of the deep Arctic water in the Pacific than in the Atlantic or Indian oceans: according to Defant (1928), in the most northern part of this ocean a relatively small mass of water appears to make its way southwards in the Okhotsk Current, and is to be found on the west side at a depth of some 500–1500 m. between lats. 15° and 50° N.; Wüst, however, has put forward the view that the Arctic Intermediate current in this ocean is a strong current which flows southward until it meets the Antarctic current near the Equator. Below a depth of some 2000 m. in the central part of the Pacific lies a mass of water which, according to Sverdrup, extends on the north-eastern side of a line drawn from a point at lat. 40° S., long. 100° W. through Fiji to Japan, and this mass he attributes to an eastward current of water from the Atlantic and Indian Antarctic Oceans, especially the latter, which enters the Pacific Ocean south of Australia (*vide* Deacon, 1937, p. 100).

The greater part of the Pacific Ocean appears to be filled with this water that is very uniform in salinity and temperature, and there is no obvious mass of warm intermediate water, such as we have seen in the North Atlantic and North Indian regions, flowing southward from the north to the south Pacific regions to form an intermediate current; but it appears probable that there is a slow movement of water from north to south, and that some at least of this "intermediate" water swings eastward between Cape Horn and the Antarctic continent. In southern latitudes the last part of the Antarctic Bottom Drift passes right across the Pacific Ocean, and reaches as far as the western side of Graham Land but no further: as Deacon (1938) points out, "on the east side (of Graham Land) the bottom water is newly formed, but on the west side it has travelled round the whole (Antarctic) continent." Deacon (1938) also points out that the recent observations of the "Discovery" "confirm the theories put forward by Professor Wüst, Dr. Möller and Dr. Sverdrup as to the existence of an eastward movement from the Atlantic Ocean through the Indian Ocean to the Pacific Ocean in the warm deep layer; they show that the deep current is almost circumpolar, and while some of it spreads northwards with the Antarctic bottom water, there appear to be compensating movements towards the south in the upper part of the current. In the Indian Ocean such a movement is likely to contain a mixture of waters from the North Indian deep current and the Antarctic Intermediate Current, and in the Pacific Ocean a mixture of waters from the intermediate and bottom currents formed somewhere in the tropical part of the ocean."

With any reduction in the amount of flow of the Sub-polar intermediate water and its failure to pass across the Equator or beyond lat. 15° N., we should expect to find a corresponding reduction in the number of Atlantic and Indian species that have been recorded from the north-west Pacific area, when compared with the catches made in the northern region of the Indian Ocean or in the south-west and south-east Pacific areas.

Our knowledge of the fauna of the north-west region of the Pacific Ocean is still somewhat scanty, and is derived mainly from the work of Giesbrecht (1892), Kurasige (1901), Marukawa (1921), Mori (1932), Tanaka (1937) and Wilson (1942). Unfortunately the work of the "Carnegie," with which Wilson's report deals, was limited to the top 100 m., and hence there can be little doubt that many more deep-dwelling species still await discovery. Our knowledge of the north-east Pacific region is more extensive, thanks to the work of Giesbrecht (1892 and 1895), Esterly (1905, 1906, 1911, 1913 and 1924), Campbell (1929) and Wilson (1942). I have given below the species that have been recorded from these two areas :

West and North-west Pacific area.	East and North-east Pacific area.
*_Calanus cristatus_ Kröyer.	_Calanus cristatus_ Kröyer.
*_C. finmarchicus_ (Gunn.).	_C. finmarchicus_ (Gunn.).
*_C. helgolandicus_ (Claus).	. .
. .	*_C. hyperboreus_ Kröyer.
*_C. propinquus_ Brady.	_C. propinquus_ Brady.
C. syumpuensis Kurasige.	. .
*_C. tenuicornis_ Dana.	_C. tenuicornis_ Dana.
*_C. tonsus_ Brady (= _plumchrus_ Marukawa).	. .
*_Calanoides brevicornis_ (Lubb.).	. .
*_Neocalanus gracilis_ (Dana).	_Neocalanus gracilis_ (Dana).
*_N. robustior_ (Giesbr.).	_N. robustior_ (Giesbr.).
*_Megacalanus princeps_ Wolfend.†	_Megacalanus princeps_ Wolfend.
*_Bathycalanus princeps_ Brady (= _rigidus_ Sars).	_Bathycalanus princeps_ Brady.
*_Ctenocalanus vanus_ Giesbr.	_Ctenocalanus vanus_ Giesbr.
*_Microcalanus pusillus_ Sars.	_Microcalanus pusillus_ Sars.
*_Pseudocalanus elongatus_ (Boeck).	_Pseudocalanus elongatus_ (Boeck).
*_Eucalanus attenuatus_ (Dana).	_Eucalanus attenuatus_ (Dana).
. .	_E. bungii_ Giesbr. f. _bungii_.‡
. .	_E. bungii_ Giesbr. f. _californicus_.
*_E. elongatus_ (Dana).	_E. elongatus_ (Dana).
*_Rhincalanus nasutus_ Giesbr.	_Rhincalanus nasutus_ Giesbr.
*_Spinocalanus abyssalis_ Giesbr.	_Spinocalanus abyssalis_ Giesbr.
. .	*_S. caudatus_ Sars.
. .	*_S. magnus_ Wolfend.
. .	_S. major_ Esterly.
*_Eucætideus giesbrechti_ (Cleve).	. .
*_Ætideus armatus_ (Boeck).	_Ætideus armatus_ (Boeck).
. .	_Ætideopsis divaricata_ Esterly.
. .	_Æ. pacifica_ Esterly.
*_Chiridius poppei_ Giesbr.	_Chiridius poppei_ Giesbr.
?*_C. gracilis_ Farran.	. .

† As Vervoort (1946, p. 56) has pointed out, the "species" described by Marukawa (1921, p. 13, pl. i, figs. 10–13 and pl. ii, figs. 1–4) under the name _Pseudolovenula magna_ gen. et sp. nov., is a young stage of a species belonging to the Family Megacalanidæ nov. Vervoort suggests that it is an example of the IVth Copepodid stage of _Megacalanus princeps_ Wolfend., but this, I think, is improbable, since Marukawa has shown the posterior thoracic margin as uniformly rounded, whereas in _M. princeps_ it is produced in a rounded projection, and the 2nd basal segment of the 1st leg shows no sign of the spine that is characteristic of this species.

‡ Vervoort (1946, p. 91), from a study of the examples of the species of _Eucalanus_ in the "Snellius" collections from the Malay Archipelago, has reached the conclusion that the separation of _Eucalanus elongatus_ and _E. bungii_ cannot be maintained, and that it is only possible to recognize an Atlantic form with a spinous process on the 5th thoracic segment and a Pacific form with a smoothly rounded posterior thoracic margin.

* Denotes a North Atlantic species.

West and North-west Pacific area.	East and North-east Pacific area.
..	*_Chirundina streetsi_ Giesbr.
Paratharybdis frontalis Tanaka.	..
..	*_Gætanus armiger_ Giesbr.
..	_G. ascendens_ Esterly.
..	_G. brevicornis_ Esterly (= _rectus_ Wolf.).
..	_G. intermedius_ Campbell.
..	*_G. latifrons_ Sars.
..	*_G. miles_ Giesbr.
*_Gætanus minor_ Farran.	_G. minor_ Farran.
..	*_G. kruppi_ Giesbr. (= _clarus_ Esterly).
..	*_G. pileatus_ Farran (= _caudani_ auct.).
..	_G. secundus_ Esterly.
..	_Gaidius pungens_ Giesbr.
*_Gaidius tenuispinus_ Sars.	_G. tenuispinus_ Sars.
..	*_Euchirella amœna_ Giesbr.
*_Euchirella brevis_ Sars.	_E. brevis_ Sars.
*_E. curticauda_ Giesbr.	_E. curticauda_ Giesbr.
..	*_E. galeata_ Giesbr. (? = _bitumida_ With).
..	_E. granulata_ A. Scott.
..	*_E. messinensis_ (Claus).
..	_E. propria_ Esterly.
*_E. pulchra_ (Lubb.).	_E. pulchra_ (Lubb.).
*_E. rostrata_ (Claus).	_E. rostrata_ (Claus).
..	_E. simplex_ Esterly.
..	*_E. truncata_ Esterly (= _intermedia_ With).
..	_Undeuchæta bispinosa_ Esterly.
..	_U. incisa_ Esterly (? = _superba_ With).
*_Undeuchæta major_ Giesbr.	_U. major_ Giesbr.
*_U. plumosa_ (Lubb.).	_U. plumosa_ (Lubb.).
..	_Euchæta diegensis_ Esterly.
Euchæta japonica Marukawa.	_E. japonica_ Marukawa (? = _elongata_ Esterly).
..	_E. solida_ Esterly (= _tenuis_ Esterly).
..	*_E. spinosa_ Giesbr.
..	_E. tenuis_ Esterly.
..	_Paraeuchæta californica_ (Esterly).
..	_P. dubia_ (Esterly).
Paraeuchæta flava (Giesbr).	..
..	_P. propinqua_ (Esterly).
..	_P. spinifera_ (Esterly).
*_P. tonsa_ (Giesbr.).	_P. tonsa_ (Giesbr.).
*_Phænna spinifera_ Claus.	_Phænna spinifera_ Claus.
Xanthocalanus medius Tanaka.	..
..	_Xanthocalanus pulcher_ Esterly.

West and North-west Pacific area.	East and North-east Pacific area.
..	_X. similis_ Esterly.
..	_X. tectus_ Esterly.
..	*_Heteramalla dubia_ (T. Scott).
Onchocalanus nudipes Wilson.	_Onchocalanus nudipes_ Wilson.
..	_O. latus_ Esterly.
*_Scottocalanus securifrons_ (T. Scott).	..
..	*_Scottocalanus persecans_ (Giesbr.).
..	*_Lophothrix frontalis_ Giesbr.
..	*_L. latipes_ (T. Scott).
Scaphocalanus gracillicauda Tanaka.	..
..	*_Scaphocalanus magnus_ (T. Scott).
S. minutus Tanaka.	..
S. pacificus Mori.	..
*_Scolecithricella abyssalis_ (Giesbr.).	_Scolecithricella abyssalis_ (Giesbr.).
..	_S. aculeata_ (Esterly).
..	_S. angusta_ Esterly.
*_S. auropecten_ (Giesbr.).	_S. auropecten_ (Giesbr.).
*_S. ctenopus_ (Giesbr.).	_S. ctenopus_ (Giesbr.).
*_S. dubia_ (Giesbr.).	..
..	_S. elephas_ (Esterly).
..	_S. longirostris_ (Esterly).
S. marginata (Giesbr.).	_S. marginata_ (Giesbr.).
..	_S. mollis_ (Esterly).
..	_S. pacifica_ Esterly.
..	_S. obscura_ (Esterly).
S. porrecta (Giesbr.).	_S. porrecta_ (Giesbr.).
..	*_S. similis_ (T. Scott).
..	_S. subdentata_ Esterly.
..	_S. vorax_ Esterly.
*_Amallothrix emarginata_ (Farran).	_Amallothrix emarginata_ (Farran) (= _inornata_ (Esterly)).
..	*_Temoropia mayumbæensis_ T. Scott.
..	*_Metridia bœcki_ (Giesbr.).
*_Metridia brevicauda_ Giesbr.	_M. brevicauda_ Giesbr.
..	_M. curticauda_ Giesbr.
..	_M. ignota_ Esterly.
*_M. longa_ Lubb.	..
*_M. lucens_ Boeck.	_M. lucens_ Boeck.
..	*_M. princeps_ Giesbr.
*_M. venusta_ Giesbr.	_M. venusta_ Giesbr.
*_Pleuromamma abdominalis_ (Lubb.).	_Pleuromamma abdominalis_ (Lubb.).
P. gracilis (Claus) (? _borealis_ (Dahl)).	_P. gracilis_ Claus ?
..	*_P. quadrungulata_ (Dahl).
*_P. robusta_ (F. Dahl).	_P. robusta_ (F. Dahl).

West and North-west Pacific area.	East and North-east Pacific area.
**P. xiphias* (Giesbr.).	*P. xiphias* (Giesbr.).
..	**Gaussia princeps* (T. Scott) (=*atra* Esterly).
**Lucicutia clausi* (Giesbr.).	*Lucicutia clausi* (Giesbr.).
**L. grandis* (Giesbr.).	*L. grandis* (Giesbr.).
..	**L. longicornis* (Giesbr.).
**L. longiserrata* (Giesbr.).	..
..	**L. ovalis* Wolfend.
..	**Heterorhabdus abyssalis* (Giesbr.).
**Heterorhabdus clausi* (Giesbr.).	*H. clausi* (Giesbr.).
**H. papilliger* (Claus).	*H. papilliger* (Claus).
**H. spinifrons* (Claus).	*H. spinifrons* (Claus).
..	*H. tanneri* (Giesbr.).
..	**H. vipera* (Giesbr.).
..	**Heterostylites longicornis* (Giesbr.).
..	*Disseta maxima* Esterly (? = *scopularis* Brady).
**Disseta palumboi* Giesbr.	*D. palumboi* Giesbr. (= *grandis* Esterly).
D. scopularis Brady.	..
..	**Augaptilus longicaudatus* (Claus).
..	**A. megalurus* Giesbr.
**Euaugaptilus bullifer* (Giesbr.).	..
..	*Euaugaptilus californicus* (Esterly).
..	*E. depressus* (Esterly).
..	**E. hecticus* (Giesbr.).
..	*E. lamellifer* Esterly.
..	**E. nodifrons* Sars (? = *simplex* Wolfend.).
**E. palumboi* Giesbr.	*E. palumboi* Giesbr.
..	*E. romanus* (Esterly). ♂ only.
..	*E. rostratus* Esterley.
**E. squamatus* Giesbr.	..
..	**Centraugaptilus horridus* (Farran) (= *pyramidalis* (Esterly)).
..	*C. lucidus* Esterly.
..	**C. rattrayi* (T. Scott) (= *macrodus* Esterly).
..	*C. porcellus* Johnson.
**Haloptilus acutifrons* (Giesbr.).	*Haloptilus acutifrons* (Giesbr.).
**H. angusticeps* Sars.	..
..	**H. chierchiæ* (Giesbr.).
**H. longicornis* (Claus).	*H. longicornis* (Claus).
**H. ornatus* (Giesbr.).	*H. ornatus* (Giesbr.).
..	**H. oxycephalus* (Giesbr.).
**H. plumosus* (Claus).	*H. plumosus* (Claus).
**H. spiniceps* (Giesbr.).	*H. spiniceps* (Giesbr.).

West and North-west Pacific area.	East and North-east Pacific area.
..	_Arietellus pacificus_ Esterly.
..	*_A. setosus_ Giesbr.
..	*_A. simplex_ Sars (= _major_ Esterly).
..	*_Paraugaptilus buchani_ Wolfend.
..	*_Phyllopus bidentatus_ Brady.
? *_Phyllopus helgæ_ Farran.	..
..	_P. integer_ Esterly.

In the north-west and west Pacific region we have records of 75 deep-sea species, and of these as many as 62, marked by an asterisk, are known to occur in the North Atlantic Ocean: but of these species, 13 are in all probability really boreal-Arctic in their habitat, and have been swept into both the Atlantic and Pacific Oceans by currents flowing southwards. These Arctic species are—

Calanus cristatus Kröyer,
C. finmarchicus (Gunn.),
C. helgolandicus (Claus),
C. tonsus Brady,
Ctenocalanus vanus Giesbr.,
Microcalanus pusillus Sars,
Pseudocalanus elongatus (Boeck),
Spinocalanus abyssalis Giesbr.,
Ætideus armatus Brady,
Gaidius tenuispinus Sars,
Metridia longa Lubb,
Haloptilus acutifrons (Giesbr.),
H. spiniceps (Giesbr.),

and to these we should perhaps add *Euchirella rostrata* (Claus), which, though not recognized as a true arctic species, has been recorded from the Arctic region on the west coast of Greenland as far north as lat. 63° 50′ N., long. 54° 25′ W., and *Eucalanus bungii* Giesbr. with its two subspecies *bungii* and *californicus* Johnston, which, according to Johnson (1938), appears to have been swept into the north Pacific area from the Arctic, or at least from the Alaskan region through the Bering Sea.

If we exclude these Arctic species we are left with 47 species that in all probability originated in the North Atlantic Ocean and have spread thence to the north-west Pacific region, and 40 of these have been taken in both the Indian Ocean and the south-west Pacific area. Seven other species, namely:

Metridia lucens Boeck.,
Lucicutia grandis (Giesbr.),
L. longiserrata (Giesbr.),
Euaugaptilis palumboi Giesbr.,
E. squamatus Giesbr.,
Haloptilus plumosus (Claus),
Phyllopus helgæ Farran,

are known from the Atlantic and south-west Pacific regions, though they have not as yet been recorded from the Indian Ocean.

As regards the influx from the Arctic Ocean into the north Pacific Ocean, Defant (1928) remarks: " Vom Ochotskischen Meere im Westen, vom Bering-Meere in der Mitte geht im Norden der arktische Zwischenstrom aus. Seine Ausbildung steht jener des antarktischen kaum nach; die Tiefenlage seine Kernschicht ist 800 bis 900 m. im Westen, 800 m. om Zentralschnitt, seine Reichweite gegen Süden im Westen bis etwa 10° N., in der Mitte bis etwa 15° N." The Okhotsk Sea, however, is not itself connected with the Arctic Ocean, and the influx of Arctic water into the Pacific Ocean must come through the Bering Sea; this seems to be brought about by the Oya-shio Current that runs southward on the west side of the Bering Sea. There seems little or no reason to doubt that the true Atlantic species have been swept eastward from the south Atlantic Ocean in the eastern branch of the North Atlantic Intermediate Current across the southern part of the Indian Ocean, and past the south of Australia into the south-west Pacific region, and have made their way northwards up the west side of the Pacific Ocean, so that many have reached the region round Japan. A few species may have reached this region by more than one route, for of the various species noted above that seem to have come in from the Arctic Ocean, at least four have been taken in areas along the course of the North Atlantic Intermediate Current; thus *Gaidius tenuispinus* Sars, *Metridia longa* Lubb. and *Haloptilus acutifrons* (Giesbr.) have been recorded from the Indian Ocean, into which they cannot possibly have been carried by a current from the Arctic Ocean and must have been introduced from the southern side, and *Spinocalanus abyssalis* Giesbr. and *Haloptilus spiniceps* (Giesbr.) are known from the south-west Pacific region, though they have not as yet been taken in the Indian Ocean. It may be that these last two are members of a group of species that have been carried from the Atlantic Ocean southwards into the Antarctic region, and have made their way thence into the Pacific Ocean by the Antarctic Intermediate Current, for there are in all some 25 species that are known from the North Atlantic and Antarctic oceans and have also been taken in the north-west Pacific region, and some of these have not been recorded from the Indian Ocean, as for instance *Metridia lucens* Boeck, *Lucicutia grandis* (Giesbr.) and *Phyllopus helgæ* Farran.

It is interesting to note that up to the present time not a single species that has originated in the Indian Ocean, a list of which is given above (*vide supra*, p. 540), has been recorded from the north-west Pacific area, and only two species that seem to have had their origin in the south-west Pacific area, namely *Disseta scopularis* Brady and *Euaugaptilus squamatus* Giesbr., appear to have been able to get to this region, and this is in agreement with what we know of the movement in the western region of the Antarctic Intermediate Water.

As in other areas, a certain number of species appear to have arisen in this region and may be regarded as indigenous, namely:

Calanus syumpuensis Kurasige.
Paratharybdis frontalis Tanaka.
Euchæta japonica Marukawa (? = *elongata* Esterly).
Xanthocalanus medius Tanaka.
Onchocalanus nudipes Wilson.
Scaphocalanus gracillicauda Tanaka.
S. minutus Tanaka.

Scaphocalanus pacificus Mori.
Scolecithricella marginata (Giesbr.).
Scolecithricella porrecta (Giesbr.).
Paraeuchæta flava (Giesbr.).

It seems to be possible, though not easy, for species to be carried from the north-west area of the Pacific ocean to the north-east side, for of the above only three appear to have spread eastward. Of these *Euchæta japonica* Marukawa seems to me to be the same species as *E. elongata* Esterly, and *Onchocalanus nudipes* Wilson and *Scolecithricella porrecta* (Giesbr.) have been recorded from both the north-east and south-east regions of the Pacific Ocean.

From the north-east region of the Pacific I have been able to collate references to as many as 143 species of deep-sea Copepods, and of these only 54 have been recorded from the north-west region ; 91 species are known to occur in the Atlantic Ocean, but of these as many as 42 have not yet been recorded from the north-west Pacific area. Such a marked difference must be attributed at least in part to the more intensive study that has been made in the north-east area, especially by Esterly, but it seems possible that it may in part be due to the distribution of the deep-water currents in the mid-Pacific region. and more particularly to the manner in which the Atlantic-Indian Intermediate Current spreads out towards the north and east in this ocean. A certain number of species appear to have reached this north-eastern area either directly, or indirectly through the north-western region, from the Arctic Ocean, the only differences between the two areas being that whereas *Calanus helgolandicus* (Claus) has been recorded from the west side, its place is taken on the east side by *Calanus hyperboreus* Kröyer, and the presence on the east side of *Eucalanus bungii* Giesbr. and its two subspecies.* Johnson (1938) remarks that the oceanic circulation of the North Pacific, so far as it is known, lends support to the idea that the route followed in the development of these subspecies may well be northwards along the Asiatic coast and southwards along the American coast. The subspecies *bungii bungii* is a boreal and sub-boreal form from the Bering Sea and extends along the Californian coast as far as lat. 50° N., and *bungii californicus* has been taken as far north as lat. 50° N., but its southern limit is not known. They would thus seem to follow the general trend of the surface circulation, namely the Kuro-siwo, the North Pacific Drift and the California Current, clockwise round the North Pacific Ocean.

Of the 88 species that are known from the north-east Pacific region, but have not as yet been taken in the north-west area, half, 42 in all, are Atlantic forms and are widely distributed, 34 of them being known from the Indian Ocean, though 5 of these last have not as yet been recorded from the south-west Pacific region. These five species are :

Pleuromamma quadrungulata (Dahl).
Gaussia princeps (T. Scott).
Heterorhabdus vipera (Giesbr.).
Centraugaptilus horridus (Farran).
C. rattrayi (T. Scott).

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* Giesbrecht (1892, p. 149) recognized several varieties of the species *Eucalanus elongatus* (Dana), namely *hyalinus*, an Atlantic form with points on the 5th thoracic segment, *inermis* with the 5th thoracic segment smoothly rounded and with marked pubescence on the free thoracic segments and the abdomen, and *bungii*, resembling *inermis*, but with a head longer and more pointed. Johnson (1938) has raised *bungii* to the rank of a species and has described two subspecies, *bungii* and *californicus*.

Three species have been recorded from the Atlantic and the south-west Pacific areas, but have not yet been recorded from the Indian Ocean, namely :

Euchirella amœna Giesbr.
Heteramalla dubia (T. Scott).
Lophothrix latipes (T. Scott).

It seems highly probable that further researches will reveal the presence of these species in the intermediate areas.

Of the species that seem to have originated in the Indian Ocean (*vide supra*, p. 540), 4 or 5 have succeeded in penetrating into this north-east area of the Pacific, namely :

Gætanus brevicornis Esterly,
Undeuchæta bispinosa Esterly,
Euchæta tenuis Esterly,
Paraeuchæta spinifera Esterly,

and perhaps *Heterorhabdus tanneri* Giesbr.

Three, or possibly four, species that seem to have originated in the south-west Pacific area have turned up again in the north-east region, namely :

Euchirella granulata A. Scott,
Paraeuchæta propinqua Esterly,
Scolecithricella longifurca (Giesbr.),

and possibly *Disseta scopularis* Brady, if this last is the same species as *D. maxima* Esterly, as seems at least possible, for *D. scopularis* is known only from the male and *D. maxima* only from the female. The evidence appears to indicate that there is a greater connection between the south-west Pacific and Indian regions with the north-east Pacific area than with the north-west region of the Pacific. This may perhaps be explained, if we adopt Wüst's view (*vide supra*, p. 554), by the greater volume of the Arctic Intermediate water in the Pacific Ocean as compared with the Atlantic Ocean, and the fact that the rotation of the earth will tend to throw this southerly moving current of water on to the asiatic or west side of the Ocean, and thus prevent the northward spread of species beyond the Equator on this side of the Ocean, or, if we follow Sverdrup, to the mass of water, derived from the Atlantic and Indian Oceans, that fills the basin of the Pacific to the east and north-east of the line drawn from Fiji to Japan and which enters this ocean to the south of Australia.

A number of species, 37 in all, have now been recorded from the north-east Pacific region, but have not been taken in any other area ; and it seems probable that they are indigenous and endemic in this region. These species are as follows :

Spinocalanus major Esterly.
Ætideopsis divaricata Esterly.
Æ. pacifica Esterly.
Gætanus secundus Esterly.

G. ascendens Esterly.
Euchirella propria Esterly.
E. simplex Esterly.
E. solida Esterly, ♂.
? *Undeuchæta incisa* Esterly (? = *superba* With).
Paraeuchæta californica (Esterly).
P. dubia (Esterly).
Xanthocalanus pulcher Esterly.
X. similis Esterly.
X. tectus Esterly.
Onchocalanus latus Esterly.
Scolecithricella aculeata (Esterly).
S. angusta (Esterly).
S. elephas (Esterly).
S. longirostris (Esterly).
S. mollis (Esterly).
S. pacifica Esterly.
S. obscura (Esterly).
S. subdentata Esterly.
S. vorax Esterly.
Lucicutia longicornis (Giesbr.).
Metridia ignota Esterly.
? *Disseta maxima* Esterly.
Euaugaptilus californicus (Esterly).
E. depressus (Esterly).
E. lamellifer Esterly.
E. romanus (Esterly).
E. rostratus Esterly.
Centraugaptilus lucidus Esterly.
C. porcellus Johnson.
Arietellus pacificus Esterly.
A. major Esterly.
Phyllopus integer Esterly.

Up to the present time not a single one of these species has been reported from any other area, and a possible explanation of this limited distribution may perhaps be found in the character of the water movements in this ocean. Deacon (1945), in a review of the oceanographical results of the last voyage of the "Carnegie," remarks that "the measurements confirm that no highly saline water sinks from the surface into the deep layer and highest salinities in the deep water are found near the bottom, where water of Atlantic and Indian Ocean origin creeps slowly northwards from the Southern Ocean. Compared with the deep-water circulation in the Atlantic Ocean, the Pacific deep water movements are very sluggish." It thus seems probable that any "migration" southwards from this northern region of the Pacific Ocean would be against the current.

There are two or three species that have, up to the present time, been recorded from this north-east region of the Pacific Ocean and the Atlantic Ocean only: these are—

? *Undeuchæta incisa* Esterly (? = *U. superba* With).
Amallophora similis T. Scott.
Paraugaptilus buchani Wolfend.

As regards the first, if I am right in thinking that *Undeuchæta superba* and *U. incisa* are synonyms, this species may have entered the north Pacific area from the Arctic region through the Bering Strait, for *U. superba* has been recorded by With (1915) from as far north in the Atlantic Ocean as lat. 65° N. off the east coast of Greenland and in the Faroe-Iceland Channel. In both *Amallophora* and *Paraugaptilus* we have small genera composed of only very few species. In *Amallophora* two species, *typica* and *similis*, occur in the Atlantic Ocean, and of these *similis* has managed to get into the south-west and north-east areas of the Pacific Ocean. Similarly, in the genus *Paraugaptilus*, *P. buchani* occurs in both the north Atlantic and in the north-east Pacific areas, while the second species in the genus, *similis*, has been taken only in the south-west Pacific region. It seems probable that we have here two rare genera which originated in the North Atlantic Ocean and have been swept southwards and then eastwards, as so many other species and genera appear to have been, and that in the genus *Paraugaptilus* transference from one habitat to another has been accompanied by the evolution of a new species, *Paraugaptilus similis*, in the south-west Pacific.

The south-east region of the Pacific is perhaps the least known of all the oceanic areas, and we are dependent on Giesbrecht (1892) and Wilson (1942) for the relatively little that we know. It seems possible that in one part of this area conditions are unfavourable for the existence of many planktonic organisms. Agassiz (1906) found that the northern limit of this unfavourable area " forms a regular curve from off the Paumotus, cutting long. 100° W. at 10° S. lat., and thence curves in an easterly and south-south-easterly direction, cutting lat. 20° S. at about 84° W. long." ; he also notes that " the southern limit of the poor pelagic trawls begins off the east face of the Paumotus, running east, somewhat north and south of lat. 20° S. to about 95° W. long., when it runs off in a south-easterly direction." Within this area Agassiz found that all trawls between 300 and 800 fms. (550 and 1460 m.) yielded in the main only dead and decomposing material, and in one instance as many as 65% of the Copepoda were dead. Graham (1943), from his examination of the catches of Phyto-plankton made by the " Carnegie " in her last cruise, reached the conclusion that in the south-east part of the Pacific Ocean between the coast of South America and long. 120° W. there is a barren region with a very low plankton production ; this area is bounded by the edges of what he terms the Antarctic Drift (presumably by this he means the West Wind Drift), the Peruvian Current and the westward extension of the Peruvian Current. Wilson (1942, p. 7), in his comparison of the different parts of the Pacific Ocean, notes that " in the South Pacific the stations yielding the most species were located in the eastern part alongside the Humbolt Current and in the western part north of the Samoan Islands." During the " Carnegie " 's last cruise the barren area noted by Agassiz was crossed twice, once between Stas. 44 and 50 and again between Stas. 56 and 70, while Stas. 70 to 95 run from east to west along the line of this barren area. It is extremely interesting to compare the numbers of deep-sea species that were captured in the various tow-nettings at these stations and I have tabulated these below : at most stations three serial tow-nettings, at 0 m., 50 m. and 100 m.

depth, were taken at each station, but at some of them only one or two tow-nettings were taken, and I have indicated these by an asterisk :

Number of Station.	Number of deep-sea Copepoda.	Number of Station.	Number of deep-sea Copepoda.	Number of Station.	Number of deep-sea Copepoda.
44	22	56	25	74	14
45	10	57	14	75	15
46	5	58	10	*76	4[1]
47	5	59	5	*77	—[2]
48	10	60	1	*78	8[1]
49	14	61	7	79	9
50	16	62	5	*80	8[3]
		63	4	*81	9[3]
		64	5	*82	6[3]
		65	10	*83	6[3]
		*66	9[1]	*84	5[3]
		67	8	*85	10[3]
		68	11	*86	4[3]
		69	16	*87	7[3]
				*88	4[3]
				*89	8[3]
				*90	3[3]
				*91	5[3]
				*92	4[3]
				*93	7[3]
				94	9
				*95	12[4]
				96	12
				97	14

[1] At 0 and 100 m.
[2] At 0 m. only.
[3] At 0 and 50 m. only.
[4] At 50 and 100 m. only.

These figures certainly seem to corroborate the assertion that in this region there is a considerable reduction in the number of species of deep-sea Copepoda, though the paucity of numbers of species taken within the top 100 m. may be due to a condition of stability in the water layers and an absence of turbulence. In the deeper levels the density of population does not appear to be affected, for at "Carnegie" Sta. 64, where a tow-netting was taken at a depth of 1000 m., the number of deep-sea species captured was 47.

From this south-east region of the Pacific Ocean I have been able to collate records of the occurrence of 92 different deep-sea species, namely :

**Calanus finmarchicus* (Gunn.).
**C. helgolandicus* (Claus).
**C. propinquus* Brady.
**C. tenuicornis* Dana.
**C. tonsus* Brady.

Calanoides patagoniensis (Brady).
**Neocalanus gracilis* (Dana).
**N. robustior* (Giesbr.).
**Megacalanus princeps* Wolfend.
**Bathycalanus princeps* Brady.
**Microcalanus pusillus* Sars.
**Pseudocalanus minutus* Kröyer (= *elongatus* (Boeck)).
**Eucalanus attenuatus* (Dana).
**E. elongatus* (Dana).
**Rhincalanus nasutus* Giesbr.
**Spinocalanus abyssalis* Giesbr.
**S. caudatus* Sars.
**S. magnus* Wolfend.
**Euætideus giesbrechti* (Cleve).
**Ætideus armatus* (Boeck).
**Æ. bradyi* A. Scott.
**Gætanus armiger* Giesbr.
**G. kruppi* Giesbr.
**G. miles* Giesbr.
**G. minor* Farran.
**Gaidius affinis* Sars.
**G. tenuispinus* Sars.
Euchirella bella Giesbr.
**E. brevis* Sars.
**E. curticauda* Giesbr.
**E. intermedia* With (= *truncata* Esterly).
**E. messinensis* (Claus).
**E. galeata* Giesbr. (? = *bitumida* With).
**E. pulchra* (Lubb.).
**E. rostrata* (Claus).
**Undeuchæta major* Giesbr.
**U. plumosa* (Lubb.).
**Undinopsis bradyi* Sars.
**Pseudochirella divaricata* (Sars).
**Valdiviella minor* Wolfend.
**Paraeuchæta incisa* (Sars).
**P. tumidula* (Sars).
**Phænna spinifera* Claus.
Onchocalanus nudipes Wilson.
**Heteramalla dubia* (T. Scott).
**Lophothrix frontalis* Giesbr.
**L. humilifrons* Sars.
**Scaphocalanus magnus* (T. Scott).
**S. medius* Sars.
**Scolecithricella abyssalis* (Giesbr.).
**S. auropecten* (Giesbr.).

S. marginata (Giesbr.).
S. porrecta (Giesbr.).
S. spinacantha Wilson.
**Amallothrix emarginata* (Farran).
**A. obtusifrons* Sars.
**A. propinqua* Sars.
**Metridia bœcki* Giesbr.
**M. brevicauda* Giesbr.
**M. curticauda* Giesbr.
**M. longa* (Lubb.).
**M. lucens* Boeck.
**M. princeps* Giesbr.
**Pleuromamma abdominalis* (Lubb.).
**P. gracilis* (Claus).
**P. quadrungulata* (Dahl).
**P. robusta* (Dahl).
**P. xiphias* (Giesbr.).
**Lucicutia bicornuta* Wolfend.
**L. clausi* (Giesbr.).
**L. curta* Farran.
**L. longicornis* (Giesbr.).
**Heterorhabdus abyssalis* (Giesbr.).
**H. compactus* Sars.
**H. papilliger* (Claus).
**H. spinifrons* (Claus).
**H. vipera* (Giesbr.).
**Heterostylites longicornis* (Giesbr.).
**Augaptilus longicaudatus* (Claus).
**Euaugaptilus filigerus* (Claus).
**Haloptilus acutifrons* (Giesbr.).
**H. chierchiæ* (Giesbr.).
**H. longicornis* (Claus).
**H. ornatus* (Giesbr.).
**H. oxycephalus* (Giesbr.).
**H. plumosus* (Claus).
**H. spiniceps* (Giesbr.).
**Isochæta ovalis* Giesbr.
**Phyllopus bidentatus* Brady.
**P. helgæ* Farran.
**Mormonilla minor* Giesbr.
**M. plasma* Giesbr.

Of the above species no less than 86 are known to inhabit the Atlantic Ocean, thus constituting 93·5 per cent. of the total population. I have marked these species in the above list with an asterisk. Of the remaining 6 species, two—

Calanoides patagoniensis (Brady),
Euchirella bella Giesbr.,

have been recorded from the Indian Ocean. Four species, namely—

Scolecithricella spinacantha Wilson,
S. marginata Giesbr.,
S. porrecta (Giesbr.).
Onchocalanus nudipes Wilson,

appear to be confined to the Pacific Ocean and may be regarded as indigenous, and possibly endemic, the three last occurring in both the north-east and north-west areas.

I have already called attention to the present state of our knowledge of the deep water movements in the southern Pacific Ocean (*vide supra*, p.554), and the composition of the deep-water copepod fauna is exactly what one would expect to find. The great majority of the species recorded from this south-east region can have been transported eastward in the Atlantic-Indian Intermediate water, and most of them have already been recorded from both the Indian Ocean and the south-west Pacific region; there are, however, certain species that have not been recorded from one or other section of this southern route.

The following twelve species have so far not been recorded from the Indian Ocean:

†*Calanus tonsus* Brady,
†*Spinocalanus abyssalis* Giesbr.,
Ætideus bradyi A. Scott,
Gaidius affinis Sars,
Heteramalla dubia (T. Scott),
Amallothrix propinqua Sars,
†*Metridia lucens* Boeck,
Haloptilus plumosus (Claus),
†*H. spiniceps* (Giesbr.),
†*Phyllopus helgæ* Farran,
Mormonilla minor Giesbr.,
†*M. phasma* Giesbr.,

and a further group of seven, though present in the Indian Ocean, have not been recorded from the south-west Pacific region, namely:

†*Spinocalanus magnus* Wolfend.
†*Euchirella rostrata* (Claus).
Valdiviella minor Wolfend.
Lophothrix humilifrons Sars.
†*Metridia longa* (Lubb.).
Heterorhabdus vipera (Giesbr.).
†*Haloptilus oxycephalus* (Giesbr.).

Out of these nineteen species, however, as many as ten have been taken in the sub-Antarctic and Antarctic regions and I have indicated these with a † in the lists above. These species may well have been swept southwards from the Atlantic in the North Atlantic Intermediate Current to the sub-Antarctic region, and then have been carried northwards again in the sub-Antarctic intermediate or the Antarctic Bottom water and so have reached the south-east Pacific area.

Nine species, namely,

Spinocalanus caudatus Sars,
Paraeuchæta incisa (Sars),
P. tumidula (Sars),
Scolecithricella (*Amallophora*) *similis* T. Scott,
Lucicutia curta Farran,
L. longicornis (Giesbr.),
Heterorhabdus compactus Sars,
Isochæta ovalis Giesbr.,
Paraugaptilus buchani Wolfend.,

are, so far as we know at present, confined to the Atlantic Ocean and the eastern Pacific region. It seems very doubtful whether these can be regarded as a relict fauna from the early Tertiary time when there was a direct connection between these two areas, and it seems far more likely that they are rare species and in consequence have only been taken on very few occasions, but that they have followed the same dispersal route as so many other Atlantic species.

The evolution of new species in this south-eastern area of the Pacific Ocean seems to be a matter of extreme rarity, perhaps correlated with the unfavourable character of the water in the 550–1460 m. level (*vide supra*, p. 564); I know of only a single species, *Scolecithricella spinacantha* Wilson, that may be regarded as endemic.

When attempting to review the distribution of the pelagic Copepoda of the Antarctic region, it is essential, as Ottestad (1932) has pointed out, to discriminate, so far as our present knowledge will permit, between species that are sub-Arctic and are inhabitants of the West Wind Drift and the Antarctic Intermediate water, and those that are truly Antarctic and may be found in the Antarctic Bottom Drift. It is, I think, justifiable to conclude that the plankton of the West Wind Drift is circum-global in its distribution. I have already (*vide supra*, p. 513) given a list of some 96 species from the North Atlantic that have been taken in the sub-Antarctic and Antarctic regions, and thanks to the work of Brady (1883), Giesbrecht (1902), Wolfenden (1908, 1911), T. Scott (1912), Farran (1929), and Hardy and Gunther (1935), we have records of the following additional species that have been taken in this sub-antarctic zone:

Calanus acutus Giesbr.,
C. propinquus Brady,
C. simillimus Giesbr.,
Drepanopus pectinatus Brady,
Rhincalanus gigas Brady,
Spinocalanus antarcticus Wolfenden,
Euchirella hirsuta Wolfend.,
E. latirostris Farran,
E. spinosa Wolfend.,
Gaidius major Wolfend. (= *brevispinus* Sars),

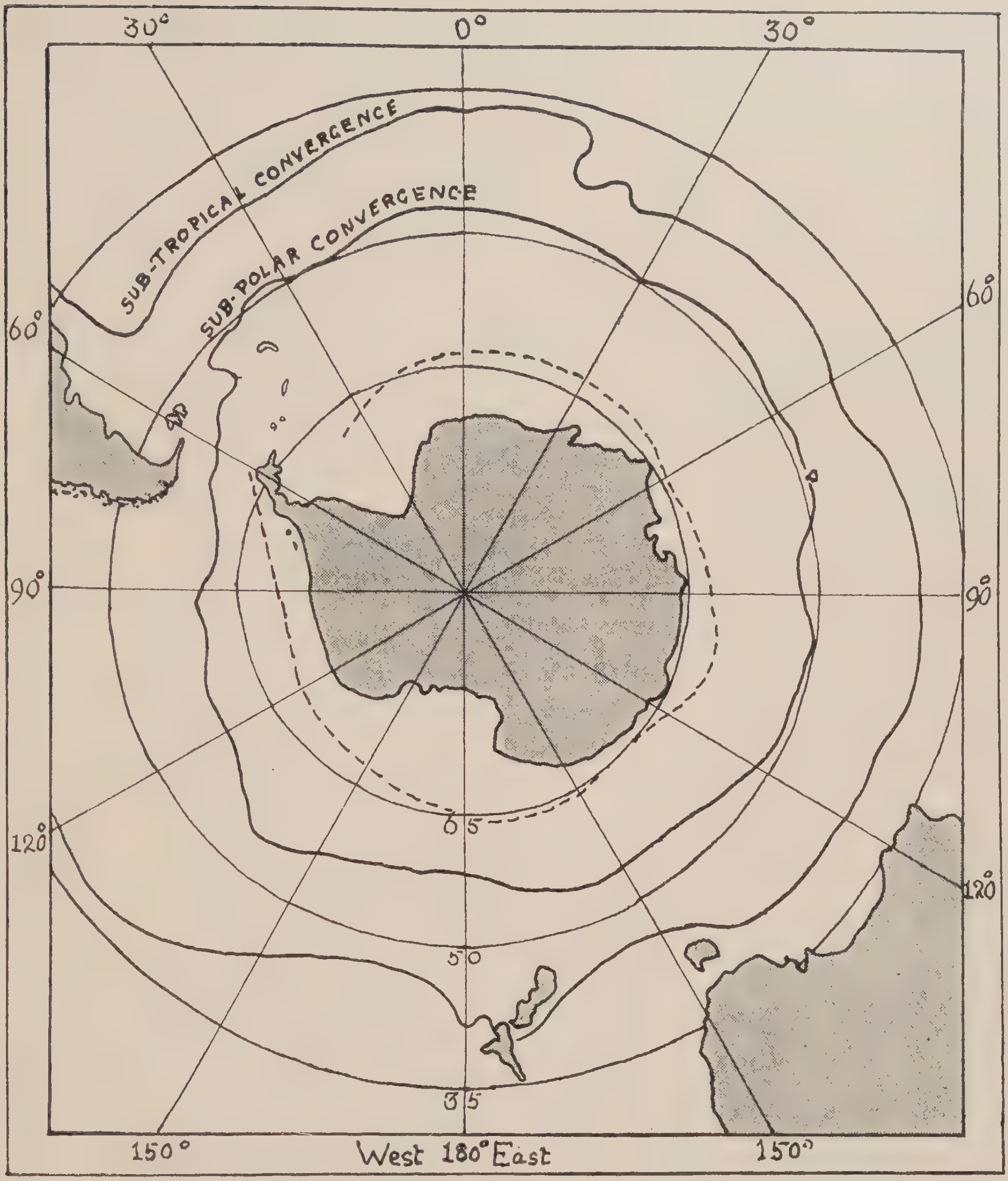
Mesogaidius intermedius Wolfend.,
Paraeuchæta biloba Farran,
Xanthocalanus gracilis Wolfend.,
Scolecithricella echinatus (Farran),
S. glacialis (Giesbr.),
Racovitzanus antarcticus Giesbr.,
Temora kerguelensis Brady,
Lucicutia frigida Wolfend.,
Metridia curticauda Giesbr.,
M. gerlachei Giesbr.,
Heterorhabdus austrinus Giesbr.,
Candacia cheiura Cleve,
Oncœa curvata Giesbr.,

and to these should, perhaps, be added *Heterorhabdus tanneri* Giesbr., *Acartia lilljeborgii* Giesbr., *A. simplex* Sars (if this species be specifically distinct from *A. clausi* Giesbr.), *Cyclopina pusilla* Sars and *Ectinosoma australe* Sars (if this be distinct from *E. melaniceps* Boeck and *E. antarcticum* Giesbr.).

These last three species have been recorded by Sars (1905) from brackish water in Chatham Island in the Pacific Ocean; this island lies in lat. 44° 20′ S., long. 176° 0′ E. east of New Zealand, and not very far from the northern boundary of the West Wind Drift as indicated by the sub-tropical convergence line.

The water of the West Wind Drift enters the Atlantic Ocean through Drake Passage, and here it becomes mixed with Antarctic water that has been deflected northwards on the west side of Graham Land into the southern side of the Strait, and again as it enters the Scotia Sea the West Wind Drift water is joined by water that is flowing out of the Weddell Sea.

On both the northern and southern sides of the West Wind Drift, that is at both the Sub-tropical and Antarctic Convergence lines (*vide* Text-figs. 94 and 95), there seems to be a considerable mixture of water. At the Sub-tropical convergence line the sub-Antarctic water sinks down and moves southwards underneath the West Wind Drift at a depth of some 80–200 m., and can be followed, at any rate in the South Atlantic Ocean, as far almost as the Antarctic convergence, while in places the sub-tropical water extends southwards above the sub-Antarctic water, thus driving the sub-tropical convergence line towards the south, and Deacon (1937) suggests the possibility that tongues of sub-Antarctic water are occasionally driven across the usual position of the Antarctic convergence line towards the south-east; but he (1937, p. 35) states that "there is no indication of a movement of sub-Antarctic water southwards over the Antarctic water in the western part of the Indian Ocean." Below the surface of the West Wind Drift there is, between the Sub-tropical and Antarctic convergence zones, a sub-surface current, composed of water derived partly from the sub-Antarctic and partly from sub-tropical water, that tends to flow southwards; in the Atlantic Ocean this lies at a depth of about 100–150 m., but as we follow it eastward the depth at which this southward current is found gradually increases. In the region to the south of the Cape of Good Hope it lies between 300–400 m. at the northern side and climbs to 100–150 m. at its southern limit; in the central part of the Indian Ocean it is situated at a depth of 400–600 m., and here is probably largely

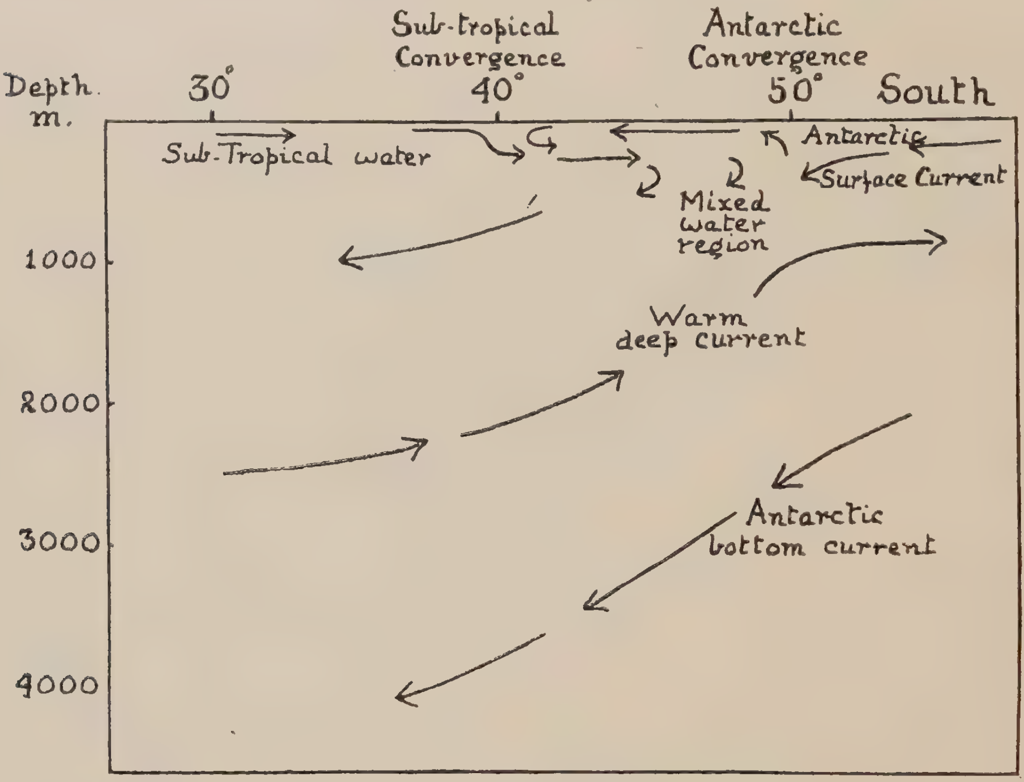


Text-fig. 94.—The Sub-tropical and Sub-polar (Antarctic) Convergence Zones (after Deacon, 1938). – – – – – – Approximate position of the boundary between the East and West Wind drifts in the Antarctic Zone.

composed of water from the Agulhas Current that has been deflected eastward ; in the Pacific Ocean the strength of this southward flow is considerably reduced and it lies again at a somewhat higher level, namely 300–400 m.

This sub-surface current of sub-tropical water will tend to carry with it tropical and sub-tropical plankton southwards towards the Antarctic convergence beneath the West Wind Drift, and this may perhaps account for the presence of large numbers of such species as *Clausocalanus arcuicornis* (Dana), *Oncæa notopus* Giesbr. and *Scolecithricella* *minor* (Brady) at depths of approximately 250–500 m. between lats. 50° and 54° S. in the Atlantic sector of the Antarctic (*vide* Hardy and Gunther, 1935), and the occurrence of *Clausocalanus arcuicornis* (Dana) and *Oncæa* spp. at 385–400 m. and 300 m. respectively in the Indian Sector (*vide* Wolfenden, 1911).

A few species that are definitely Antarctic in their origin appear to have been able to pass northwards across the Antarctic convergence into the West Wind Drift, and Hardy and Gunther (1935) have recorded that a number of species are not limited in their distribution by this convergence line. The following species have been recorded in the layer between 0 and 250 m. on both sides of the line :



Text-fig. 95.—The vertical Circulation in the South Atlantic Ocean (after Deacon, 1938).

Calanus propinquus Brady.
C. simillimus Giesbr.
Metridia lucens Boeck.
Drepanopus pectinatus Brady.

With regard to the first of these, Hardy and Gunther (1935, p. 356) suggest that there are two separate races, a purely Antartic race and a sub-Antartic one. Other species that are not limited in their distribution by this barrier are :

Calanus acutus Giesbr.
Rhincalanus gigas Brady.
? *Euchirella hirsuta* Wolfend.
Mesogaidius intermedius Wolfend.

Spinocalanus antarcticus Wolfend.
Paraeuchæta antarctica Giesbr.
Scolecithricella glacialis (Giesbr.).
Metridia curticauda Giesbr.
Metridia gerlachei Giesbr.
Heterorhabdus austrinus Giesbr.
Racovitzanus antarcticus (Giesbr.).

In certain species transference across the convergence line into the West Wind Drift appears to be correlated with small changes of structure. Steuer (1932, 1933) has attempted to correlate certain forms of species of *Pleuromamma* with the water masses in which they were living; thus he gives *Pleuromamma quadrungulata* (Dahl), f. *psychrophila* and *P. gracilis* (Claus), f. *maxima* as inhabitants of the West Wind Drift, and Farran (1929, p. 265) has described a variety of *Heterorhabdus austrinus* Giesbr., mainly characterized by its small size, that possesses a habitat extending from the true Antarctic region to as far north as lat. 40° S.

A certain number of species appear to have had their origin in the West Wind Drift. Russell (1935, p. 10) gives the following species as examples of this fauna :

Calanus simillimus Giesbr.,
? *Eucalanus acus* Farran (? =*E. longiceps* Matthews),
Clausocalanus laticeps Farran,
Paraeuchæta biloba Farran,
Candacia cheiura Cleve,

and to these should be added—

Clausocalanus paululus Farran,
? *Drepanopus forcipatus* Giesbr.,
D. pectinatus Brady,
Euchirella latirostris Farran,
Temora kerguelensis Brady,
Copilia hendorfi Dahl,
Centropages auklandicus Kramer (= *discaudatus* Brady),

and probably—

Heterorhabdus tanneri Giesbr.,
Acartia lilljeborgi Giesbr.

The first of these, *Calanus simillimus* Giesbr., however, is in all probability a true Antarctic species, and the claim of the second, *Eucalanus acus* Farran, depends on whether this species is, or is not, a synonym of *E. longiceps* Matthews, and is the same as the species described by With (1915, p. 52) under the name *Eucalanus attenuatus ?*, which was taken in the North Atlantic Ocean as far north as lats. 57°–61° N.

Ottestad (1932) has put forward the view that only those species that occur in the upper stratum of the Antarctic region, namely the upper 200 m., in which the water is characterized by a salinity of less than 34·5 °/₀₀ and by a negative temperature, should be regarded as truly Antarctic ; those that occur at a greater depth from 200–1500 m., where the water has a higher salinity and a positive temperature, he designates "sub-Antarctic."

It is, however, somewhat doubtful whether this distinction can be maintained, at any rate as regards a number of these southern species, for the work of the "Discovery" (*vide* Hardy and Gunther, 1935) has shown that they may exhibit a very clear vertical migration that is sufficient to carry them out of one stratum into the other. The following species may be regarded as truly Antarctic (*vide* Giesbrecht, 1902; Quidor, 1906; Wolfenden, 1908 and 1911; T. Scott, 1912; Farran, 1929; Hardy and Gunther, 1935; and Wilson, 1938):

Calanus acutus Giesbr.
C. propinquus Brady.
C. simillimus Giesbr. (= *aculeatus* Brady).
Rhincalanus gigas Brady.
Stephus antarcticus Wolfend.
S. longipes Giesbr.
S. neptuni Cleve.
Spinocalanus antarcticus Wolfend.
S. magnus Wolfend.
Drepanopsis frigidus Wolfend.
Chiridius antarcticus (Wolfend.) (= *Faroella antarctica* Wolfend.).
C. minor (Wolfend.) (= *Faroella minor* Wolfend.).
C. polaris Wolfend.
Pseudochirella elongata (Wolfend.).
Euchirella rostromagna Wolfend.
E. elongata Wolfend.
Gætanus antarcticus Wolfend.
Chirundina antarctica Wolfend.
Paraeuchæta antarctica (Giesbr.).
P. austrina Giesbr.
P. erebi Farran.
P. rasa Farran.
P. similis (Wolfend.).
Xanthocalanus antarcticus Wolfend.
X. gracilis Wolfend.
X. tenuiserratus Wolfend.
Onchocalanus frigidus Wolfend.
Cephalophanes frigidus Wolfend.
Scolecithrix polaris Wolfend.
S. glacialis Giesbr.*
S. incisa Farran.
Scaphocalanus impar (Wolfend.) (= *Amallophora impar* Wolfend.).
S. sub-brevicornis (Wolfend.) (= *Amallophora sub-brevicornis* Wolfend.).
Amallophora altera Farran.
Racovitzanus antarcticus Giesbr.
Metridia curticauda Giesbr.

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* According to Brady (1918, p. 23) this species is synonymous with *Scolecithrix römeri* Mrazek that has been recorded from the Arctic Ocean; if this be the case, the species is bipolar in its habitat.

M. gerlachei Giesbr.
Lucicutia frigida Wolfend.
Heterorhabdus austrinus Giesbr.*
H. pustulifer Farran.
Euaugaptilus antarcticus (Wolfend.).
E. cornutus (Wolfend.).
Haloptilus ocellatus Wolfend.
Paralabidocera antarctica (Thompson) (= *hodgsoni* Wolfend.).
Temoropsis simplex Wolfend.
Oithona frigida Giesbr.
?*Oncœa curvata* Giesbr.

In addition to the above, Brady (1918) has described several new genera and species from the collections made by the Australian Antarctic Expedition, 1911–14, but in a number of cases it appears highly probable that he was dealing with immature examples, and many of his descriptions are so inadequate that it is impossible, without a careful examination of the material, to determine whether his new genera and species can be accepted. A list of these species is given below :

Diarthropus torticornis gen. nov., sp. nov.
Spinocalanus giesbrechti sp. nov.
Streptocalanus typicus gen. nov., sp. nov.
Gœtanus antarcticus sp. nov. (*non* Wolfenden).
Gaidius glacialis sp. nov.
Euchirella plumosa sp. nov.
E. tumida sp. nov.
Paraeuchœta plumifera sp. nov.
Euchœtopsis haswelli gen. nov., sp. nov.
Pseudoothrix anatina gen. nov., sp. nov.
Plagiopus australis gen. nov., sp. nov.
Metridia andrœna sp. nov.
M. trispinosa sp. nov.
Pleuromamma wolfendeni sp. nov.
Heterorhabdus farrani sp. nov.
H. nigrocinctus sp. nov.
Stephus simillimus sp. nov.

Ottestad regards *Calanus acutus* Giesbr., *Calanus propinquus* Brady and *Metridia gerlachei* Giesbr. as true Antarctic species, whereas *Calanus simillimus* Giesbr., *Rhincalanus gigas* Brady and *Metridia curticauda* Giesbr. he regards as sub-Antarctic. Lying below the water of the West Wind Drift there is, as already mentioned, a sub-surface southward-moving mass of water, composed in part of a return current of sub-Antarctic water and in part of sub-tropical water (*vide* Text-fig. 95) ; this return current can be detected in all three oceans, though it lies at somewhat different levels in each, and in places it reaches to within 100 miles of the Antarctic convergence. At its southern extremity this current meets with a mass of true Antarctic surface water that is moving northwards, and is sinking down at the Antarctic convergence line to form the Antarctic Intermediate Current that flows northwards above the southwardly-moving warm Intermediate water from the northern and tropical regions of the three oceans, Atlantic, Indian and Pacific. The strength of this Antarctic Intermediate Current varies very considerably in the different oceans (*vide* Chart II); in the Atlantic it flows northwards past the Equator, flowing up the western side and then spreading out eastward across the South Atlantic into the Gulf of Guinea, while a weaker branch flows northwards towards the south-west point of Africa (*vide* Wüst, 1936, fig. 5); in the Indian Ocean it also flows northwards in the main on the western side of the ocean, and reaches as far as the Gulf of Oman, but on the eastern side it seems to vary very considerably in strength. The "Snellius" expedition found it to be strongly developed in the equatorial region on the eastern side, but the "Dana" expedition found no trace of it in lat. 5° N. Steuer (1933, p. 296) states that Defant informed him that this Intermediate current is absent in the Bay of Bengal, and on this he bases his explanation of the presence of large examples of *Pleuromamma xiphias* (Giesbr.), that are characteristic of the Antarctic Intermediate water, in the Arabian Sea and their absence from the Bay of Bengal. In the Pacific Ocean the Antarctic Intermediate water reaches on the western side as far as the equator or even lat. 16° N. Below the warm Intermediate Current lies the Atlantic Bottom Drift, but the most recent work on this deep current (*vide* Deacon, 1938) indicates that this mass of water has a single origin in the Weddell Sea, and that, sinking down in this area, it flows steadily eastward and northward through all the three oceans, mixing as it goes with water from other sources such as the Atlantic and Indian Intermediate Currents. In the Atlantic Ocean this bottom drift passes up the western basin as far as lat. 40° N., and a branch enters the eastern basin through the Romanche Channel near the Equator and then spreads northwards as far as lat. 35° N. and southward to the Walfisch Ridge in lat. 20°–35° S. Another branch passes northwards in the eastern part of the south Atlantic between the tip of the Mid-Atlantic Ridge and the Crozet Bank and spreads out south-west of Africa as far as the Walfisch Ridge. In the Indian Ocean one mass of Antarctic bottom water flows northwards between the Crozet Bank and the Kerguelen-Gaussberg Ridge and flows northwards up the western series of basins into the Arabian Sea, while a second mass passes north on the east side of the Kerguelen-Gaussberg Ridge into the eastern basin and the Bay of Bengal. In the Pacific Ocean the Antarctic Bottom water has become mixed with Atlantic and Indian Intermediate water flowing eastward past the south of Australia, and then this combined mass spreads eastward and northward.

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* Farran (1929, p. 265) seems to doubt whether this species can be regarded as distinct from *H. norvegicus* Boeck. He remarks, " the females scarcely differ except in their slightly larger size from the North Atlantic species which I have referred (1908, 1926) to *H. norvegicus* " ; and as regards the male, he notes that " they do not differ in any noticeable degree from those of *H. norvegicus*." There are slight differences in the 5th legs of both sexes between these two species.

It thus seems clear that while the species that inhabit the region of the West Wind Drift may be swept northwards towards the Equator in the Antarctic Intermediate water, the true Antarctic species may be carried in this direction by either the Antarctic Intermediate water or by the Antarctic Bottom Drift. According to Farran (1929, p. 291), *Copilia hendorfi* Dahl "seems to have a continuous distribution from New Zealand by way of Australia to South Africa"; I should prefer to place these regions in the inverse order, and regard the distribution as extending from South Africa past Australia to New Zealand. Reference to the chart of its distribution given by Lehnhofer (1926, p. 165) shows that in the majority of instances this species has been taken between lats. 20° and

40° S., and most, if not all, of these catches appear to have been made in the uppermost few metres, but Steuer (1933, p. 289) states that examples were taken in the Indian Ocean at "Valdivia" Sta. 170 in lat. 32° 54′ S., long. 83° 02′ E. at a depth of 1750–1000 m., and among the "John Murray" collections was an example taken at Sta. 131 in lat. 1° 39′ 06″ S., long. 61° 13′ 48″ E. in a haul between 500–0 m. Both these last depths correspond to the Antarctic Intermediate Current. Other records of the presence of species that are known to be inhabitants of the West Wind Drift considerably to the north of this current have been given by Cleve (1904); he has recorded *Candacia cheiura* Cleve from the region of the Benguela Current at a depth between 275 and 450 m., and in the south-western part of the Indian Ocean beneath the Agulhas current of *Heterorhabdus austrinus* Giesbr. at a depth of 530–780 m., and *H. tanneri* Giesbr. at 900 m. depth.

Steuer (1933, p. 296) has suggested that Antarctic copepods can pass far to the north into tropical regions through the action of the Antarctic Deep current: this may be true of a few species, but a study of the depths at which these Antarctic species have been taken seems to render it more probable that the greater number have been distributed northwards by the agency of the Antarctic Intermediate Current. A number of Antarctic species have been taken far to the north in various regions of all three great oceans. One such region lies to the west and south-west of the Cape of Good Hope in the South African "Mischgebiet"; here Cleve (1904) recorded *Stephos neptuni* Cleve at a depth of 250–350 m., and, if Wolfenden (1911) be correct in his assumption that the form recorded by Cleve from this region under the name *Metridia lucens* Boeck was in reality *M. gerlachei* Giesbr., this species, too, has been taken here in a depth of only 250–450 m. In the same area *Metridia curticauda* Giesbr. was taken by the "Valdivia" in depths of 1000 and 3000 m., *Rhincalanus gigas* Brady in a depth of 1200 m., and both *Euchirella hirsuta* Wolfend. and *Mesogaidius intermedius* Wolfend. in a depth of 3000 m. *Metridia curticauda* Giesbr. has been recorded from lat. 12° 11′ S., long. 6° 11′ W. at a depth of 2000 m., and from lat. 20° 44′ N., long. 31° 54′ W. at the same depth, and Wilson (1942) has reported it at "Carnegie" Sta. 6, lat. 50° 22′ N., long. 13° 31′ W., at the surface, but this last record is, I think, open to doubt. *Calanus propinquus* Brady was reported by the "Challenger" at Sta. 342, lat. 9° 43′ S., long. 13° 51′ W., and at Sta. 348, lat. 3° 10′ N., long. 14° 51′ W., in both instances at the surface, and Wilson (1942) has recorded it from the Caribbean Sea as far north as lat. 15° 15′ N., long. 68° 11′ W. in the top 100 m.

As just mentioned in the case of *Metridia curticauda* Giesbr., the reports of several Antarctic species being taken far to the north in the Atlantic Ocean have been regarded of doubtful reliability. Giesbrecht (1902) has already called attention to the probability that *Calanus propinquus* (Brady) and *C. simillimus* Giesbr. have been confused with each other, and Wolfenden (1911) states that according to the results obtained by the "Gauss" *propinquus* is not found west or north of the Cape of Good Hope. This latter author also considers that *Rhincalanus grandis* Giesbr. does not extend beyond this region, such records as have been made of its occurrence further to the north being due to a confusion with large examples of *Rhincalanus nasutus*, which were named *Rhincalanus gigas* by Brady and were taken in lat. 37° 17′ S., long. 53° 52′ W., and again in lat. 36° 44′ S., long. 46° 16′ W. at the surface by the "Challenger" (*vide* Brady, 1883, p. 42). I see no reason to doubt the correctness of Brady's identification, and Steuer (1933, fig. 7, p. 289) has accepted them as true records of this species, *R. gigas* Brady and *R. grandis* Giesbr. being synonyms.

Drepanopsis frigidus Wolfend. has been reported from lat. 0° 46′ N., long. 18° 59′ W. at a depth of 3000 m.; and *Drepanopus pectinatus* Brady has been reported by Wilson (1942) as far north as lat. 44° 39′ N., long. 33° 06′ W. at 100 m. Reference to the section given by Wüst (1935, pl. xxvii) of the salinity of the water on the two sides of the Atlantic Ocean shows that not one of these records is from sufficient depth to fall within the limits of the Antarctic Bottom Drift, and the fact that several of them are from the surface or the top 100 m. clearly suggests that the transfer northwards from the Antarctic region has been by the Antarctic Intermediate Current, from which by the action of turbulent movement of the water specimens have been brought up from below: this would be in conformity with Iselin's view (*vide supra*, p. 492) that water of the Antarctic Intermediate Current may join the Gulf Stream.

In the Indian Ocean the region round Kerguelen Island appears to be an area in which Antarctic species are to be found: *Calanus propinquus* Brady, *Spinocalanus antarcticus* Wolfend. and *Mesogaidius intermedius* Wolfend. have been taken here at a depth of 1200 m., and *Rhincalanus gigas* Brady has been reported here at only 70 m. depth. This last species occurs considerably further north, and has been recorded in lat. 26° 04′ S., long. 93° 44′ E. at a depth of 2200 m., in lat. 4° 06′ S., long. 73° 25′ E. in 2000 m., and in lat. 9° 06′ N., long. 53° 41′ E. in 1500 m. It is interesting to note that the depth of occurrence gets progressively less as we pass northwards. *Metridia gerlachei* Giesbr. has been recorded in lat. 24° 47′ S., long. 58° 29′ E. in 3000 m. *Drepanopsis frigidus* Wolfenden and *Metridia curticauda* Giesbr. have been able to cross the Equator, and both were taken at "Investigator" Sta. 682 in the Laccadive Sea (lat. 10° 26′ N., long. 74° 32′ 30″ E.) in a haul from 1280 m. (700 fms.) to the surface, and the "John Murray" Expedition obtained examples of *Gætanus antarcticus* Wolfend. as far north as lat. 24° 10′ 36″ N., long. 59° 00′ 36″ E. in a haul from 2500 m. As regards this last record, the mass of water in which the capture was made has been shown by Mohamed (1940, pp. 159 and 172) to be part of the Antarctic Intermediate Current. Steuer (1926*b*), in his account of the genus *Cephalophanes*, shows that whereas *C. refulgens* Sars is an Atlantic form that occurs between lats. 55° N. and 30° S., the second species in the genus, *C. frigidus* Wolfenden, is an Antarctic species that has been carried northwards. In this paper he suggests that examples are carried along in the Atlantic Ocean in the Antarctic Intermediate Current and in the Indian Ocean in the Antarctic Bottom Drift. In a later paper (1933) he again attributes the presence of *C. frigidus* in the Indian Ocean to the Antarctic Bottom Drift, but he now suggests that the presence of this species in the Atlantic Ocean in the region of the Gulf of Guinea is due to "the strong outflow of water from the Indian Ocean into the Atlantic that is brought about down to about 1500 m. by the Agulhas Current." I have already pointed out that the existence of this deep current flowing from the Indian Ocean towards the Weddell Sea in the Antarctic is no longer accepted, and it would appear to be much more probable that examples may be swept northwards into both the Atlantic and Indian Oceans by either the Antarctic Intermediate Current or by the Antarctic Bottom Drift. In the "Valdivia" collection examples were taken in the Indian Ocean at Sta. 232, lat. 3° 26′ N., long. 58° 35′ E. in a vertical haul from 1500 m. and this lies in the Antarctic Intermediate Current; other examples were taken at Sta. 215 at the southern end of the Bay of Bengal, lat. 7° 01′ N., long. 85° 57′ E. in a vertical haul from 2500 m., and if these specimens came from the extreme depth this would correspond better with the Antarctic Bottom Drift, especially in view of the doubt whether the Antarctic Intermediate Current extends so far to the north in this region. In the Atlantic Ocean the region from which examples were obtained lay in the Gulf of Guinea, at Sta. 46, lat. 1° 25′ N., long. 10° 16′ W., in a vertical haul from 3000 m., Sta. 49, lat. 0° 20′ N., long. 6° 45′ W., in a vertical haul from 3500 m., and near the region of the south African "Mischgebiet," lat. 31° 21′ S., long. 9° 46′ E., in a vertical haul from 3000 m. These depths seem to indicate that the species was living at a depth too great to be in the Antarctic Intermediate Current, and it thus seems probable that in this ocean they were swept northwards by the Antarctic Bottom Drift; their presence in the Gulf of Guinea could well be accounted for by the flow of Antarctic Bottom water from the western Atlantic Basin through the Romanche Channel.

In the Pacific Ocean Brady has recorded *Calanus propinquus* Brady from lat. 35° 41′ N., long. 157° 42′ E. at the surface, and Wilson (1942) reports its presence throughout the Pacific Ocean in the top 100 m. between lat. 16° 35′ S., long. 155° 44′ W., and lat. 40° 20′ N., long. 150° 58′ E. Brady (1883) has recorded *Rhincalanus gigas* Brady from the North Pacific Ocean as far north as lat. 35° N. between Japan and Honolulu, but this is almost certainly wrong, and he was probably dealing with examples of *Rhincalanus nasutus* Giesbr.

Finally *Oncæa curvata* Giesbr. has been recorded by Wilson (1942) at several "Carnegie" Stations between lat. 1° 32′ S., long. 93° 10′ W., and lat. 6° 32′ N., long. 80° 04′ W. at a depth of only 100 m. Farran states that this species is frequent in the Antarctic, especially under the ice at Winter Quarters, and extending northwards as far as 58° 30′ N. (sic); this must, I think, be a printer's error for 58° 30′ S.

In all these records the depth of occurrence that is given for any particular catch is the maximum at which the animal might have been living when the haul was made, and the actual habitat may have been in considerably shallower depths. With the exception of the species *Cephalophanes frigidus* Wolfend., in no instance is the depth sufficiently great to have brought the animal into the track of the Antarctic Bottom Drift, and in many instances the depth clearly corresponds either to the Antarctic Intermediate Current, or to the upper stratum of the North Atlantic or Indian Intermediate Current lying just below it, and thus corresponds reasonably closely with the depth at which, as we have already seen (*vide supra*, p. 328), the great majority of the deep-dwelling Copepoda are found. It is also significant that the majority of the Antarctic species that have been taken far to the north of the Antarctic region and in deep water north of the Antarctic convergence zone are those that, as we have seen, are able to withstand the changes encountered in a transfer from true Antarctic conditions to those that are characteristic of the West Wind Drift.

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